

A COMPARATIVE INVESTIGATION OF THE COMMERCIALY USED COLOR
PRINT PROCESSES AND THEIR POSSIBLE UTILIZATION FOR
SATISFYING THE DEMAND FOR HIGH QUALITY, LOW COST
COLOR PRINTS IN QUANTITIES FROM 12-3,000

by

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484 Beacon Street
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May 17, 1954

Professor L. F. Hamilton
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Professor Hamilton:

In accordance with the requirements for graduation, I herewith submit a thesis entitled "A Comparative Investigation of the Commercially Used Color Print Processes and Their Possible Utilization for Satisfying the Demand for High Quality, Low Cost Color Prints in Quantities From 12-3,000."

I would like to express my appreciation for the many enjoyable hours Professor Arthur C. Hardy, Professor of Photography and Optics, Massachusetts Institute of Technology, spent in discussing and advising this thesis and for suggesting and introducing me to many outside contacts. I would also like to thank Mr. Louis B. Barnes of the School of Industrial Management, Massachusetts Institute of Technology, for his aid and guidance in this writing. My appreciation is also expressed for the cooperation I received from the many companies visited. To my fiancée, Miss Joan Jacobson, who has spent so many hours in editing and preparing this thesis in its final typewritten form, I owe a sincere vote of thanks.

Sincerely yours,

Alex W. Dreyfoos, Jr.

ABSTRACT

An investigation (literature search and visits to or correspondence with many companies) of ten color print processes (Carbro, Printon, Kodachrome, Kodacolor, Ektacolor, Dye Transfer, Graphic Arts Letterpress, Offset and Graveure⁷ and Ektalith) in commercial use today, comparing quality, price, available sizes, etc., and brief description of how they work. Eight conditions are set up that a process should satisfy in order to fill the demand for low price, high quality prints in quantities from 12-3,000. Each process is viewed in the light of these conditions and when summarized, the Dye Transfer process proves to have the highest potential for filling the demand.

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INTRODUCTION

Since the first successful black and white photographs by Daguerre in 1839, men have tried to find ways to make photographs in natural color. Many experiments dot the pages of history, but the first practical solution came from the British physicist, James Clerk Maxwell, in 1861. Since then, over one hundred color processes have been tried commercially; most of them failing or giving way to newer developments.¹

This thesis was begun with the intention of investigating the present methods of reproducing color prints on paper and pointing out the particular advantages and disadvantages of each. My interest in this topic was aroused for numerous reasons; I have always been interested in photography (heretofore only black and white) and would like to enter a profession connected with this field, preferably a new enterprise. I feel that the color photographic industry is in the early stages of what will soon be a huge field and I, like most people, enjoy the beautiful color reproductions available from color transparencies; however, I dislike having to project them on a screen, view them through a viewer or hold them up to a light in order to see them. I questioned--why can't they be on paper and still look good? I knew of and had seen Kodachrome and Kodacolor prints and, of course, had seen color prints in magazines. With few

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1 "The History of Photography from 1839 to the Present",
Museum of Modern Art, New York, 1949.

exceptions, however, their reproductions left, in my mind, a great deal to be desired.

Preliminary research soon made it evident that a number of color processes are in general use today. This then was to be my thesis--to investigate the present methods of reproduction of color prints on paper.

Before the actual investigation was started, it was necessary to become familiar with the general theory of color photography. There are two general processes of color reproduction; the subtractive process and the additive process. All of the photographic processes in use today are subtractive, hence, most emphasis was placed on becoming familiar with this theory. The reader may be interested in noting that color television, however, is an additive process.

There are a number of books and pamphlets explaining the principles of color photography.² They range from books designed to give the color photographer a general idea of what goes on in the film he exposes, to technical books aimed at the research scientist in an effort to discuss the limitations of even the theoretically perfect process and determine all of the criteria that must be satisfied in order to obtain the best possible color photographs.

In the thesis proper, a few pages are devoted to explaining the basic theory of the subtractive process. There are, however, a great number of important considerations that are not discussed because space and time do not permit. In order

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2 See Appendix 1a.

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to fully cover the theory of color photography one must consider the nature of light, the visual characteristics of the eye, the effect of the light source, the viewing conditions of the print, the characteristics of black and white photographic materials, the method of forming the color image, the characteristics of colored filters and the characteristics of the colorants (dyes, pigments and inks) to mention a few. After such consideration, one may see why a color print on paper must come a great deal closer to being a more perfect reproduction than a transparency in order to be acceptable,³ and why a color transparency, projected in a darkroom, will always be capable of achieving a more life-like realism than a color print, unless the viewing conditions of the color print can be completely specified.⁴

After obtaining a basic understanding of the general theory and gaining some insight into the problems involved in achieving a high quality color print, I acquainted myself with the "how to do it" books and pamphlets⁵ on each of the processes. Reading two history books on photography⁶ helped bring the processes into the proper perspective, development wise. With a basic understanding of how the processes work, and some insight into the problems of the print maker, I saw

3 Ralph M. Evans, W. T. Hanson, Jr. and W. Lyle Brewer, "Principles of Color Photography", John Wylie & Sons, 1953, pps. 158-163.

4 Ibid.

5 See Appendix 1b.

6. See Appendix 1c.

the processes in commercial use in order to make comparisons and gain a greater knowledge of them from the people carrying them out. In the course of the year, I was able to visit fourteen companies⁷ and correspond with five other companies⁸ too distant to visit.

After starting the plant visits and talking to the company heads about the quantity range their particular process was satisfying, it became apparent that there is a niche in this field of color print reproduction that is not being filled. There is no process in general use today, that is producing high quality color prints in quantities of 12 to 3,000 at a reasonable price. Some processes in current use, are being used to fill the 1 to 12 print market and other processes are filling the market demands for quantities above 3,000. The discovery of this niche was extremely interesting to me, as a company set up to produce prints in this region might find a definite place in the color photographic industry. With this in mind, the original aim of the thesis was changed to place the emphasis on observing the processes in general use today and their possible utilization in filling this gap.

It is my feeling that of all the color processes currently being used commercially, at least one of them should potentially satisfy the necessary conditions required of a high-quality, short-run process. After some insight was gained as

7 See Appendix 2a.

8 See Appendix 2b.

to the demands of the customers of the companies visited, the following conditions were set up as being necessary to a process in order to fill the high-quality, short-run market.

1. A set up involving little or no expense.
2. Once set up, the actual print making should lend itself to mechanization to an extent that will minimize the need for highly skilled labor.
3. The cost of the materials for producing final prints should be low.
4. The process should be able to utilize a wide variety of starting material (copy work, transparencies, [all sizes] separation negatives and color negatives.)
5. The quality must be very good. (Commercial work calls for an almost exact match of subject and print. For example, the color of a dress in an advertisement. If a customer should order such a dress by mail, she may be expected to hold it right on the print, compare the color and send the dress back if they do not match.)
6. Prints must be within a close tolerance of being identical.
7. The price must be low in the 12 to 3,000 bracket if the process is to compete with existing methods. Almost any company that is able to satisfy the quality will produce the required quantity (up or down from normal) at a high price.
8. Prints must be available in a wide variety of sizes.

The reader may question the demand for color prints in this quantity range and indeed he should. I was unable to find any evidence of a market study being made; however, a number of indications of such a demand have justified, in my mind, the worth of this investigation. These are as follows:

1. The Eastman Kodak Company, the largest manufacturer of photographic equipment, is spending a considerable amount of money each year in order to develop such a process.⁹
2. Many heads of companies now producing color prints in quantities above or below this range, believe that there is a demand and wish they had a way to meet it.¹⁰
3. There are numerous companies processing black and white prints in this quantity range. While prices for black and white prints average ten cents a print in quantities of 1,000,¹¹ (and I am sure color prints can not compete at this price,) I do believe

9 This became evident during a tour of the Eastman Kodak Research Laboratories at Kodak Park, Rochester, New York.

10 Mr. Edward Evans, President, Evans Color Laboratories, Forest Hills, New York.
Mr. Alfred Losch, President, Corona Color Studios, New York, New York
Mr. L. Zoref, Associate, Kurshan & Lang, New York, New York.

11 Mr. William Sendack, Salesman, Apeda Studios, Inc., New York, New York.

companies now using black and white prints would switch to color prints if the quality and price were right.

Of the material used in this thesis, portions of the information have been taken from available literature, related to me by reliable men in the field, and the remainder is my own opinion based on what I have seen at the companies visited or concluded from a variety of questions asked at the different companies.

Most of the available literature deals with the theory of color photography or tells "how to do it" in step-by-step form. Nowhere (that I have found) are the processes evaluated one against the other and seldom are the limitations of the various processes discussed.

In the following discussions of the color print processes in use today, I have tried to give proper credit to all sources. The terms of quality that are used in the thesis are very general because of the great number of points that must be considered in defining quality, i.e., print surface, color balance, contrast, subject matter, etc.

Included in the appendices 4a-h are some samples of color prints made by the various processes. Unfortunately, these prints are valueless in the discussion as they are not uniform examples of the quality that each process will yield, i.e., the Kodacolor sample as made from a negative taken by a Kodak photographer to be especially used for advertising the process. Hence, it is a better than average

print. On the other hand, the Dye Transfer print is of lower quality than most of the prints that I saw being produced while visiting the various companies. The range of prints that were available to me was very limited as a release from the customer would be necessary before prints could be given to me. These samples were just prints that the companies had that did not require a release.

BASIC THEORY OF THE COLOR PROCESSES¹

All color processes rely on a phenomenon known for over one hundred years--that by mixing various proportions of light of any three colors, a wide range of different color sensations can be produced. By selecting the right combinations of these colored lights (called the optical primaries--red, green and blue) it is possible to match almost every natural color. The converse is also true: any color can be described as a particular combination of the three primaries (i.e., white may be described by equal amounts of red and green and blue, orange by a large amount of red, some green and no blue, etc.).

In making a color print, the first step of the basic procedure is to photograph the subject (which may be the life subject, copy work, or a color transparency) three times (from an identical position) on panchromatic, (sensitive to all colors) black and white film. (A special camera, called a one-shot camera, takes all three pictures at once and is used if the subject is not a still life subject.) One negative is exposed through a red filter, the second through a green filter and the third through a blue filter; thereby recording, on what are called separation negatives, the amount of each primary color present in each part of the subject. (See diagram--Fig. 1)

1 See Appendix 1a.

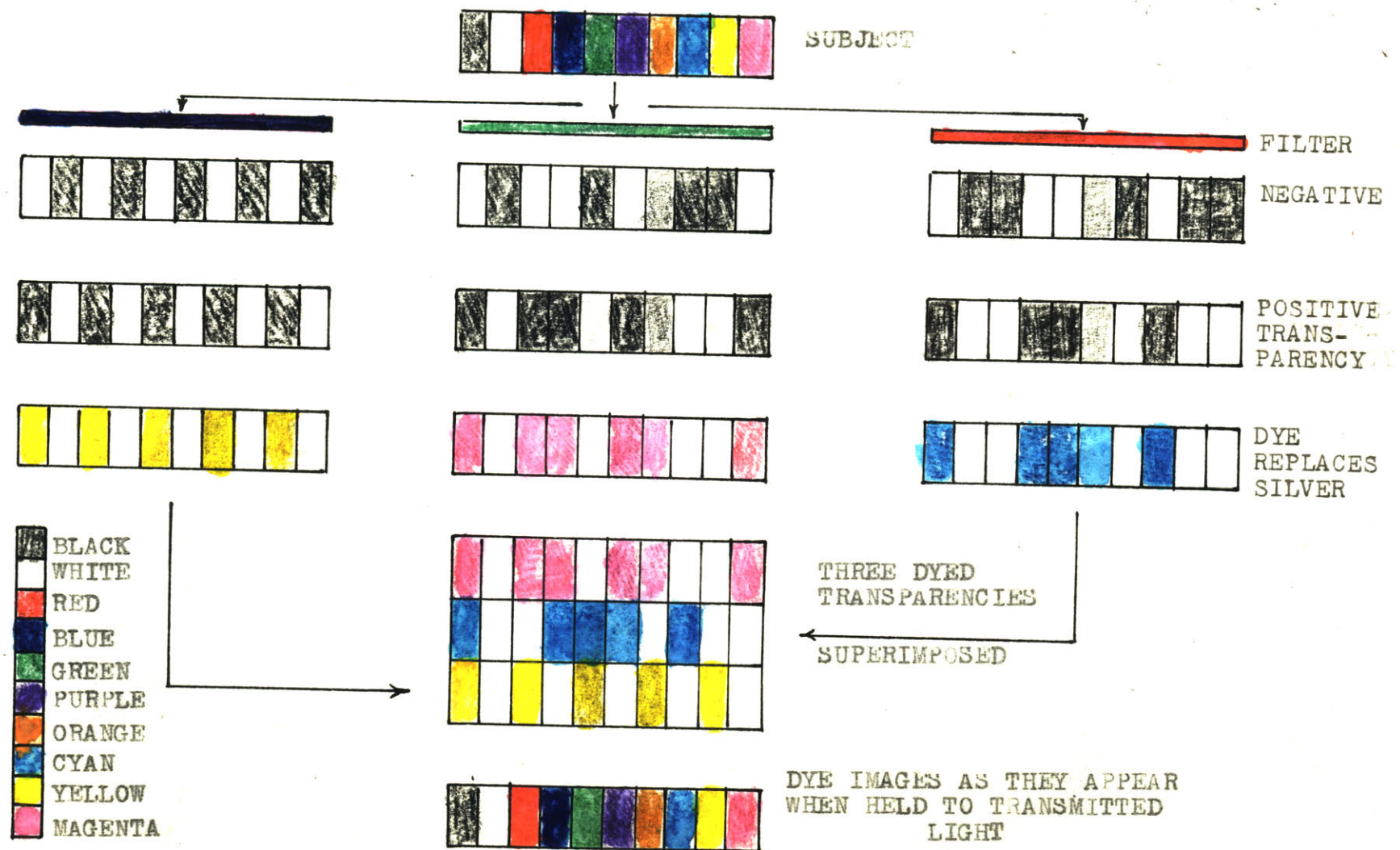


FIG. 1--SCHEMATIC DIAGRAM OF THE SUBTRACTIVE PROCESSES

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The negatives are processed as normal black and white film, and from the separation negatives, positive transparencies are made. In the transparency printed from the negative exposed through the blue filter, blues will appear white, and reds and greens, grays or blacks. In the transparency printed from the negative exposed through the green filter, green will appear white, and blues and reds, grays or blacks. Blue-greens would, of course, appear gray in each of the blue and green transparencies. The transparency from the red negative will show reds as white, and blues and greens as grays or blacks.

In order to get a color transparency, it becomes necessary to replace the silver particles (which now produce the blacks and grays) by colors. Assume that the silver can be replaced with a dye (pigment or ink)² in such a manner that where no silver existed before, no dye will be present, and where the silver particles were very dense, a large amount of dye will be deposited. (The prime difference of each

- 2 Dyes, pigments and inks (as used in subtractive processes) do not reflect colors, they only pass or absorb them. If placed against a black background, the dyes will appear black. Dyes only have color when light shines through them, such as when placed between the light source and the observer, or when placed on a white background where the light passing through the dye is reflected by the white surface and through the dye again, this light being seen by the observer. This property is dependent on the refractive index of the vehicle carrying the dye, pigment or ink particles. If the refractive index of vehicle and particle is the same, a dye, pigment or ink is formed. Paint, on the other hand, having a vehicle of different refractive index than the pigment particles, reflects color by itself and is not dependent on the surface it is applied to.

color process is in this step. As each process is explained,, the particular manner of producing the dyes will be made clear.) Where each transparency is white, the subject was either white or was the color of the filter through which it was taken. (i.e., In the blue transparency,, blues and whites appear white and all other colors appear gray or black.) This would indicate that a dye that will absorb (not pass) blue light and pass reds and greens is needed. Therefore, where no dyes appear, blue light will be transmitted and where the dye is dense, no blue will be transmitted. A yellow dye has this property. With the green negative, a dye that will absorb green and pass reds and blues is required--magenta (almost a pink) will do this. With the red negative, a cyan (green-blue) dye will absorb red and pass green and blue.

The transparencies are now bound in register, giving a colored picture which is viewed in white light (made up of red, green and blue light). Where there are no dyes, no colors are absorbed and white light passes through. Where there are equal portions of each dye, equal portions of red, green and blue, are absorbed, giving rise to grays or blacks (no light passing through). In a blue segment of the picture, cyan and magenta dyes are present, which absorb (subtract--hence the name of the process) red and green respectively, leaving (since no yellow is present) the blue light unaffected. Similar absorption gives rise to reds and greens and a combination of all the dyes in different proportions, gives rise to a wide range of colors.

In order to have a print on paper, the transparency is placed on a white background. Light passes (from the light source) through the transparency, where it is reflected by the white background again through the transparency to the observer. Since the light passes through the transparency twice, the transparency, when made for this use, should have the dyes one-half the normal density.

In carrying out this process, the print that will result will not be a true reproduction of the original subject and some method of color correction becomes necessary. This need for color correction arises from two facts:

1. Although it is possible to make a set of separation negatives that will "see" the colors of the subject in the same way that the human eye does, such negatives will not properly control the amounts of dyes necessary for perfect reproduction.³
2. A set of three subtractive printing dyes, pigments, or inks, with ideal spectral absorption, has not so far been developed.

As each subtractive-printing colored substance should absorb one of the three primary colors of white light and transmit or reflect freely the other two, the ideal cyan dye would

3 A. C. Hardy, "The Theory of Three-Color Photography", Journal of the Society of Motion Picture Engineers, Volume XXXI, No. 4, October, 1938.
A. C. Hardy and F. L. Wurzburg, Jr., "The Reproduction of Color", Interchemical Review, Volume 9, Nos. 1, 2, and 3, The Research Laboratories of the Interchemical Corporation.

absorb red light but not an appreciable amount of green or blue-violet light. The ideal magenta dye would absorb green light but not red or blue. The ideal yellow dye would absorb blue light, but not green or red. However, virtually all cyan dyes absorb considerable amounts of green and blue-violet light, although many magenta dyes absorb practically no red. There are, however, yellow dyes that are free from green and red absorption.

As a result of the absorption of green light by the cyan dye, and the absorption of blue light by both the cyan and magenta dyes, the greens and blues of a print made without color correction, appear too dark, i.e., degraded with gray. Moreover, the relative amounts of cyan, magenta, and yellow dyes printed in any portion of the picture depend upon the relative proportions of these dyes which, when superimposed, form a scale of grays. Since the cyan dye absorbs some green light, the relative amount of magenta dye printable in the scale of grays become less. Similarly, since the cyan and magenta absorb some blue light, the relative amount of yellow dye printable in the scale of grays is diminished. As a result, if the print is made without color correction, the magentas, yellows, and reds lack saturation through dilution with white.

The deficiencies of the dyes can be partially corrected in a number of ways. One of the most practical methods of color correction, capable of giving excellent results, is by

a technique known as masking.⁴ It is desired to remove, for example, from an available magenta dye (which can be regarded as a mixture of theoretically perfect magenta and cyan dyes) the cyan components. (See fig. 2 A and B) This would leave an ideal cyan dye. To do this, a low contrast positive transparency (called a mask) is made from the red filter's (cyan printing) negative and bound into register with the green filter's (magenta printing) negative. (See fig. 2 C and D) As a result, throughout the whole range of reproduced tones, in those areas where cyan is printed from the red filter negative, a little less magenta will be printed from the green filter negative. This is what is desired because the available cyan dye already in effect, contains magenta. The cyan printing negative has therefore been photographically retouched. This photographic masking method can be applied to the "correction" of the other separation negatives in a similar manner.

The oldest method of color correction is a hand correction technique, where hand work at some stage of the process, adds or lessens the amount of dye that will appear in certain parts of the print to give more correct color rendition. Although this handwork is a long, difficult and

4 R. M. Evans, W. T. Hanson, and W. L. Brewer, "Principles of Color Photography", John Wiley & Sons, Inc., New York, 1953, p. 565.
"Color Separation and Masking", Eastman Kodak Company, Rochester, New York, 1951.
D. A. Spencer, "Colour Photography in Practice", Pitman, London, England, 1948, p. 322.

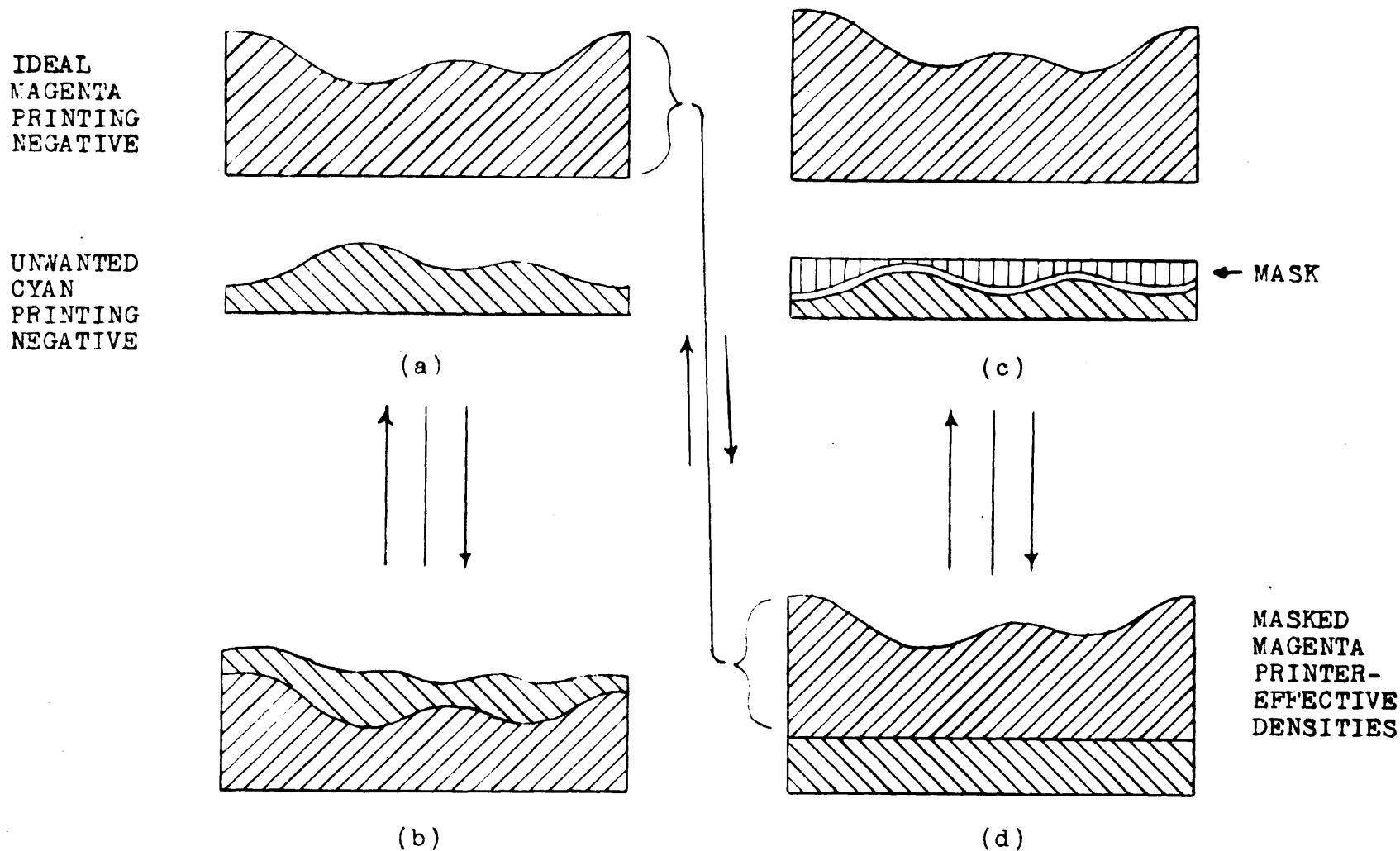


FIG. 2. DIAGRAMMATIC SECTION THROUGH A MAGENTA PRINTING NEGATIVE SHOWING DENSITIES AT EACH POINT*

*D. A. Spencer, "Colour Photography In Practice", Pitman, New York, 1948, p.325

necessarily expensive task, it is still being used to a large extent throughout the Graphic Arts industry.

A third color correction method, just starting to be used commercially, is one that is carried out electronically, through a scanning operation. This method of correction is capable of correcting the deficiencies of the dyes as well as the inadequacy of control the negatives have over the amount of dye, pigment or ink printed. This process, in its present state, is only being used in conjunction with the Graphic Arts reproduction methods.⁵

5 Arthur C. Hardy and F. L. Wurzburg, Jr., "The Reproduction of Color", Interchemical Review, Volume 9, Nos. 1, 2, and 3, The Research Laboratories of the Interchemical Corp. Arthur C. Hardy and F. L. Wurzburg, Jr., "A Photoelectric Method For Preparing Printing Plates" and "Color Correction in Color Printing", The Journal of the Optical Society of America, Volume 38, No. 4, April, 1948.

General Discussion

The modern Carbro process is an outgrowth of a carbon print process that dates back to 1905. Carbro prints today give, in the opinion of many experts, the finest color prints available. The process is long, taking an expert from six to ten hours to make one print from a set of separation negatives. There are over eighty steps involved and one mistake at any point, often necessitates starting over again. Making a second print, requires repeating the entire operation with the separation negatives as the starting point.

There are a number of small companies in New York, Philidelphia, and Chicago that process Carbro prints. (The Carbro process must be carried out at temperatures close to 65° F.; consequently, few companies south of Philadelphia use the process).

With rare exceptions, all orders for Carbros are for one or two prints. The prices charged by the New York companies are reasonably uniform, ranging from \$100 to \$125 for one print of any size up to 16 x 19 inches, if separation negatives are supplied; and from \$150 to \$175, if a color transparency of any size is supplied, thus necessitating the making of masked separation negatives. The price for the second print, since separation negatives have already been made, is again \$100 to \$125.¹ The reader may question

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1 Evans Color Laboratories, Forest Hills, New York.
Kurshan & Lang, New York, New York
Langen and Wind Carbro Prints, Inc., New York, New York

a person's willingness to pay such a high price for one picture. Actually this is a very small percentage of the total cost if, as is most often the case, the picture is to be used as copywork for the photoengraver to make plates for magazine (calender or catalogue) reproduction.

The Carbro process has other selling points besides the high quality obtainable; the prints are color fast and will retain their quality for years, and certain few subjects, such as high key subjects, will give consistently better results printed by Carbro than with any other high quality process such as Dye Transfer.

Because the entire process must be repeated for each print and so many variables must be controlled, the Carbro process does not lend itself to a quantity-run set up, due to the near impossibility of making twelve successive Carbro prints with identical results.

Technical Discussion

The Carbro process most closely follows the general theory outline of making a color print by the subtractive process. Starting with separation negatives:

1. Positive black and white prints (rather than transparencies) of the finished print size are made on a special bromide paper.
2. Sheets of pigment on a paper support (colored cyan, magenta, and yellow) are each transferred to a transparent piece of plastic and the paper support stripped off.
3. The pigment is sensitized. In this process the gelatin bearing pigment is affected so that, where it comes in contact with the silver halide image of the bromides, the gelatin will be hardened. In a subsequent warm-water wash, this hardened gelatin will remain while the remainder of the gelatin will melt and wash away, carrying with it the pigment contained in it.
4. Each bromide print is brought in contact with the sensitized pigments of the correct color. In this process the bromide images are bleached, and the gelatin is differentially hardened in proportion to the amount of silver present in the silver bromide image.
5. The pigment is removed from the bromide print and attached to another support known as the registration plastic.
6. The image is developed in warm water. At the end of this step, each of the three separation images, in its final colored form, will reside on a transparent plastic support.

7. Each of the separate images is transferred to a soluble support. This involves registering the magenta and the yellow images to the cyan, which is transferred first.

8. The three images, which are now bound together, are transferred to a final sheet of white paper and the soluble support stripped off. This is the final print and it is only now that the three-color image can be seen.

Since the several transfers require that the images dry before the next step is undertaken, it is seen that a good deal of time can transpire between the start and finish of the process.

The materials for this process are manufactured and sold by the McGraw Colorgraph Company of Burbank, California and the Auto Type Company, Ltd. of London England. Both companies also publish excellent step-by-step detailed descriptions of the process. D. A. Spencer's "Colour Photography in Practice"² also gives a fine description of the process.

Thanks to the kindness of Mr. Edward Evans (President of Evans Color Laboratories and Mr. Jerry Wind (of Langen and Wind Carbro Prints, Inc.) I had the opportunity of seeing Carbro prints being made and can attest to the fact that the Carbro print worker must be a highly skilled technician with many years of experience in order to attain the high quality prints that both companies are achieving. A Carbro worker is

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² Pitman Publishing Corporation, New York, 1938.

paid as high as \$10,000 a year. Both of these laboratories were spotlessly clean with efficiently laid out work areas, and it did not appear that costs could be lowered to an acceptable level for quantity reproduction by any further improvement in the production-line layout.

General Discussion

The Printon process was brought out by the Ansco Company of Binghamton, New York shortly after World War II. With Printon, color prints can be obtained directly (and only) from color transparencies without making separation negatives. Printon paper is exposed directly from the transparency and processed in a number of chemical baths, with the finished color print resulting. All of the steps previously mentioned as being necessary (in the Carbro process) to obtain a color print are carried out chemically in the processing. However, no masking for color correction is accomplished. Ansco sells the chemical preparation in kit form, enabling anyone capable of making black and white prints, to make Printon color prints. Many companies, previously doing only black and white work, have added Printon to their line.

Prices for 8 x 10 inch Printon prints range from \$3 to \$6 each, with discounts up to fifty percent for quantities above 500. Making duplicate prints is an entirely repetitive operation, with the exception that correct exposure and color balance have been previously determined. Printon lends itself very well to almost entirely automatic processing, (thus minimizing labor costs) and has been successfully carried out by a company in New York.¹ Only by automatic processing can successive prints be made identical to one another.

1 Pavelle Color Incorporated, New York, New York.

Printon is available in 8 inch wide rolls and in sheet sizes to 16 x 20 inches. Costs rise much more than proportionally and uniform processing (from one side of a print to the other) becomes very difficult on sizes above 8 x 10 inches. Hence, I have found only one company² offering sizes above 8 x 10 inches. Their prices are \$12 for an 11 x 14 inch print and \$25 for a 16 x 20 inch print.

The biggest disadvantages of this process, which have curtailed its commercial acceptability at the present time, are its generally poor quality and rapid fading when the print is left in bright daylight. Printon is widely used by amateur photographers who cannot afford the high first print cost of the better quality processes.

Because Printon can be processed almost automatically, it appears that if the quality could be improved, (and no doubt it will be) this process would be suitable for quantity reproduction. However, each sheet of 8 x 10 inch paper and the chemicals to process it, cost a processing company fifty-seven cents a sheet, (Ansco does not feel that this price will ever be lowered³) which is high no matter how automatically the process can be carried out. A higher quality Printon, will in the author's opinion, be best suited to fill the demands for prints in quantities up to fifty, where the lack of a high set up cost can be taken advantage of.

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2 Kurshan & Lang, New York, New York.

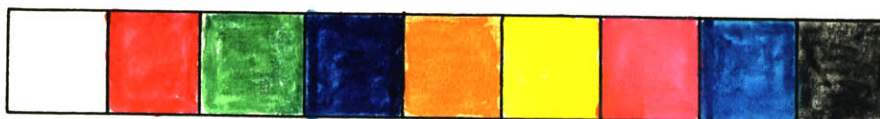
3 Ansco's Boston technical representative.

Technical Discussion

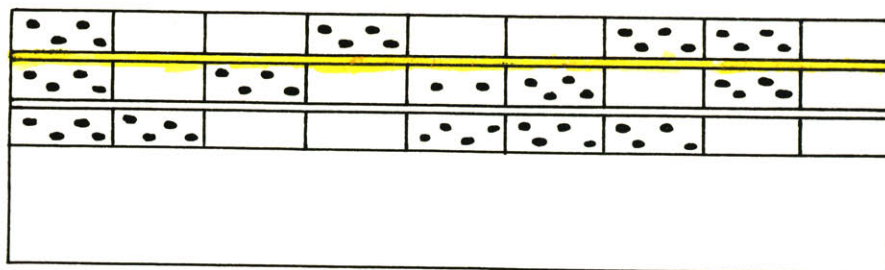
Printon is what is known as a tripack, "dye coupler" (fig. 3) reversal film which works in the following manner: The paper (actually a plastic) on which Printon color prints are made is one on which are coated (one upon the other) three emulsions, each sensitive to one of the three primary colors. When exposed to a color transparency, images are recorded on each emulsion in a manner similar to separation negatives. The film is developed to a negative, as with normal black and white film. After washing, the film is exposed to white light and redeveloped in a "color (coupler) developer."⁴ This second development chemically forms both metallic silver (that would be a positive) and color images (from colored "couplers" built in the film at the time of manufacture) in those portions of the emulsion layers unaffected by the first development. All of the metallic silver formed during the first and second development is removed by a bleaching bath, leaving only the dye images in the three emulsions. It can be seen that, in effect, separation negatives were made and developed, positive transparencies exposed and developed,

- - - - -

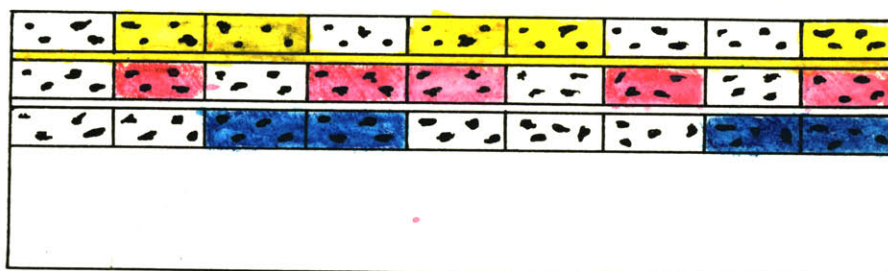
4 "A coupler developer is one in which the oxidation product of the developing agent combines with a chemical agent in the solution to form an insoluble dye. Thus, as the silver bromide is reduced to silver, the developing agent at this precise point is oxidized; and this oxidized developing agent is transferred into a dye, which is deposited along with the grains of silver." (From "Photography" by C. E. Kenneth Mees, The Macmillan Company, New York, p. 193.)



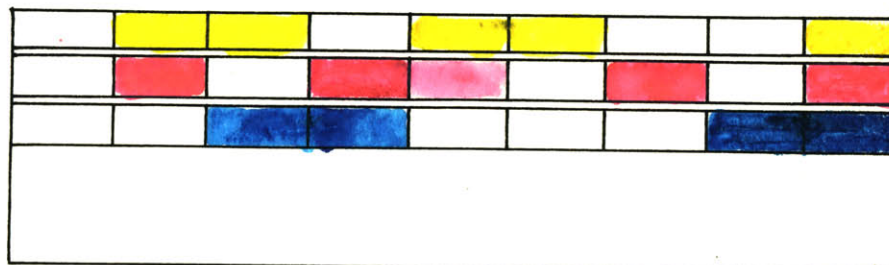
ORIGINAL TRANSPARENCY REPRESENTED SCHEMATICALLY BY COLOR PATCHES.



CROSS SECTION OF PRINT PAPER AFTER THE SILVER HALIDE GRAINS EXPOSED IN THE ENLARGER HAVE BEEN DEVELOPED TO PRODUCE NEGATIVE SILVER IMAGES.



CROSS SECTION OF PRINT PAPER AFTER THE REMAINING SILVER HALIDE GRAINS HAVE BEEN EXPOSED TO LIGHT AND DEVELOPED TO PRODUCE POSITIVE SILVER AND DYE IMAGES.



CROSS SECTION OF PRINT PAPER AFTER BOTH NEGATIVE AND POSITIVE SILVER IMAGES HAVE BEEN REMOVED, LEAVING ONLY THE POSITIVE DYE IMAGES.



DYE IMAGES AS THEY APPEAR ON THE PRINT PAPER.

REPRODUCTION OF COLORS BY A REVERSAL COLOR PRINT PAPER SUCH AS KODACHROME AND PRINTON.

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dyes released in each layer, in proportion to the silver in the positive image, and the metallic silver removed all on one film that is processed in ten solutions.

I was fortunate in visiting three companies that were making Printon prints. Two of the companies (Kurshan & Lang and Cambridge Color) were carrying out the entire operation by hand; i.e., using sheets of Printon, exposing them under a standard enlarger and placing them in film holders that attached to cables that continuously moved up and down in the solutions to provide agitation. The holders were moved from tank to tank, exposed to white light and placed in the drying cabinets all by hand.

The third company I visited was Pavelle Color Incorporated, who is the largest company producing Printon prints. The design of the Pavelle laboratories is based on the most modern discoveries and practices in the field of electronics, illumination, refrigeration, and manufacturing. The manufacturing process is divided into two distinct steps, the first step being the printing of transparencies on rolls of Printon and the second being the chemical processing of exposed rolls of Printon to produce complete color prints. The printing machine is a form of optical photographic enlarger fitted with electronic controls in the nature of phototubes used for exposure control and voltage regulators for color temperature control. The printing machines handle rolls 8 inches wide and 250 feet in length. A number of machines make it possible to produce any variety of print sizes up to 8 x 10 inches from any transparency up to 4 x 5 inches.

The chemical processing of the roll of Printon in the Pavelle laboratory is completely automatic from the time the exposed roll is started through the processing equipment until it emerges in the form of a roll of completed pictures ready for separation and distribution to the proper customers. The equipment used in processing includes a series of deep tanks each fitted with rollers near the top and bottom. Over these rollers the long strip of Printon passes, moving up and down from bottom to top continuously. After passing through the first tank, which holds the solution for the first development, the strip passes between mercury vapor lamps for the second exposure before going into the final series of tanks. All the solutions in the processing tanks are continuously replenished and agitated and are maintained at constant temperatures by means of specially designed refrigeration equipment.

Progress of the strip through the tanks is maintained by a timing mechanism which has been set in accordance with an accurate time and temperature control chart. From the time the strip is attached to the end of the strip directly preceding it through the baths and passes into the first developing bath, until it emerges from the drier tanks, it is continually moving forward. When it reaches the final stage of processing and emerges from the final solution, a water wash, it enters a compartment where it is dried by heat lamps, before being taken up in a finished roll. As may be judged from this description, Printon processing at Pavelle is a continuous operation with one roll being attached to the

end of another as rapidly as the timing permits.

I wish to take this opportunity to thank Mr. Leo Pavelle, president and Mr. Milton Berg of the Sales Department for the time they devoted to answering my questions and giving me an extensive tour of their plant.

KODACHROME PRINT PROCESS

General Discussion

In 1935 the Eastman Kodak Company brought out a 16mm color motion picture film, invented by Leopold Mannes and Leopold Godowsky, called "Kodachrome", which received widespread public acceptance. Shortly afterwards, the film was released in a variety of sizes, with 35mm film for miniature cameras (the processed transparency mounted for use in slide projectors) becoming extremely popular. The film is exposed in an ordinary camera and returned to the Eastman Kodak Company for processing.

In 1941, color prints called Kodak Minecolor prints, were being offered by Eastman in two sizes--2 $\frac{1}{4}$ x 3 $\frac{1}{4}$ inches and 5 x 7 $\frac{1}{4}$ inches. These prints were made from 35mm Kodachrome slides, and were in effect, Kodachrome film on paper. The prints were offered to the professional as Kodavachrome prints and were available in sizes from 8 x 10 inches to 30 x 40 inches. These Kodavachrome prints never attained popularity and were withdrawn from the market after the war.

Unavailable during the war, Minecolor prints were offered to the public after the war under the name of Kodachrome prints. These prints do not yield the beautiful quality of the Kodachrome transparencies and have not been generally accepted for commercial use.

The price for an 8 x 10 inch print is about \$5.00 with small discounts offered on quantity orders. Duplicate prints require a completely repetitive operation. The processing of

Kodachrome prints is done on a semi-automatic, continuous flow basis, that requires a large investment in equipment; the Eastman Kodak Company being the only company that is set up to do it. As with Printon, the cost of the print paper and the processing chemicals is high; a factor that is not desirable when thinking in terms of quantity production.

Technical Discussion

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Kodachrome, like Printon, is a tripack "dye coupler" (fig.3) reversal film. It differs from Printon mainly in the way in which the colored couplers are released, the couplers being built into the print paper and released, all at one time, in a color developer bath. In Kodachrome, the couplers are not in the print paper, but are in solution. The process works generally as follows:

After exposure by contact or enlarger printing from a color transparency, the film is developed to a negative, as with normal black and white film. The image is then removed by a bleach which dissolves the silver leaving in the film the residual silver bromide, which has not been developed as it has not been exposed. The whole film is now exposed to light and redeveloped with a coupler developer. The coupler developer is allowed to develop the entire film to silver; the coupler dye released in this reaction being a cyan. The film is next put into a bleach which transforms the silver back to silver halide and dissolves the dye. This bleach, however, is controlled in time so it only penetrates the top two emulsions, leaving the bottom one untouched. The film is now washed and the coupler developer process repeated. This reaction will take place only in the top two layers as there is no silver halide in the bottom layer. The dye released is magenta in color. The film is bleached again, the bleach being restricted to react only on the top layer. After washing, the final coupler developer reacts with the

top emulsion, releasing a yellow dye. The whole film is now acted upon by a bleach which transforms the silver to silver halide without affecting any of the dyes. The silver halide can be removed by a fix; the film then washed and dried.

The Kodachrome process relies on perfect timing to let the bleach react only so far, and involves numerous baths which make the process very complex and expensive to carry out, except on a large-scale set-up. The process is carried out only by the Eastman Kodak Company's Kodachrome Print Department in Chicago, Illinois.

KODACOLOR PROCESS

General Discussion

The Kodacolor process was put on the market in 1941, primarily for amateur photographers. Kodacolor film brings color prints within the range of the box camera owner with Kodak's old motto of "You push the button, we do the rest." Kodacolor film, upon development by Eastman, yields color negatives which are of no value by themselves, but when printed by Eastman, on Kodacolor print paper, a low cost rather grainy, fair quality, print results.

The film and the paper are of the dye coupler type, where the colors are chemically produced during processing, which lend themselves to a continuous roll automatic processing. Because the appearance of the negative is unimportant, an ingenious automatic, color correcting masking system has been built into the negative.

In order to make the film fast enough for use in box cameras and available at a low price, the quality of the print has suffered. Theoretically, a negative to positive system, such as this, will give better quality than will a double reversal process such as Kodachrome or Printon; to date, manufacturing problems and the problem of color and contrast balance in printing the negatives, have prevented the theoretical advantages of a process such as this to be realized, however, the quality of Kodacolor prints has improved steadily since 1941.

Kodacolor prints, available in sizes to 8 x 10 inches, sell for \$4 for an 8 x 10 inch print. Making duplicate prints is a completely repetative process, hence, no substantial cost reductions could be expected in quantity orders. The cost of the print paper and processing chemicals is, like Kodachrome and Printon, too high to be considered for a quantity-run process.

Technical Discussion

Kodacolor is like Printon in that it is a tripack (three emulsions on one support) "dye coupler" type process with the dye coupler built in at the time of manufacture. However, it differs from Printon in that it is not a reversal process. From the subject, Kodacolor negatives are exposed. These negatives are developed first in a color coupler developer which chemically forms both metallic silver and color dyes. Since the film has not been reversal processed, light parts of the subject appear dark, and dark parts, light. Also, through the use of the right color couplers, the colors are complementary; what is white in the subject appears black, red appears cyan (blue), green appears magenta (pink), etc. Because the color negative is a means to an end and not an end in itself, (as are color transparencies) the way the negatives look is unimportant. Because of this, it is possible, by an ingenious method, to incorporate an automatic masking into the film. This method depends for its operation on the use of colored couplers. The manner in which color couplers improve color reproduction is best considered in terms of the three emulsion layers--top, middle, and bottom--which go to make up the color negative. As we have already seen, the real function of the dye images in these layers is to control transmission of the primary colors of light--blue, green, and red respectively--through the negative when the color print is made.

For correct color reproduction, good "separation" of

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colors must be obtained, that is, each dye image must control one primary and only one. For example, the magenta image in the middle layer should absorb only green light, in varying amounts which depend on the proportions of green in the original subject. At the same time, the magenta image should transmit blue light and red light freely. Actually, an uncorrected magenta-dye image absorbs some blue light, and it therefore interferes with the proper control of blue light by the yellow dye.

The unwanted blue absorption of the magenta dye cannot be eliminated, but its effect can be neutralized by choosing a magenta-forming coupler which is yellowish in color and absorbs the same amount of blue light that would be absorbed if it were converted to magenta dye. Where the layer has been exposed, the coupler has lost its yellow color, but the blue absorption of the coupler has been replaced by the blue absorption of the magenta dye. Thus the absorption of blue light is the same everywhere in the middle layer, regardless of the distribution of exposed areas. The important result is that the magenta dye image now, in effect, absorbs only the green light which it should absorb. In other words, the combination of an actual magenta-dye image and a yellowish coupler acts like an ideal magenta-dye image plus a uniform sheet of light yellow fiber.

A similar reaction takes place in the cyan forming coupler but is not necessary in the yellow-forming coupler as the yellow dye is reasonably close to ideal. As a result

of leaving color couplers in the cyan and magenta layers, the developed negative has a strong, over-all, orange cast. In printing the negative, it is necessary to adjust the exposures through red, green, and blue filters to compensate for the absorptions added by the color-correction masks. When these adjustments have been made, the results obtained in prints closely approach those which could be obtained if dyes of perfect absorption characteristics were available.¹

Kodacolor print paper is similar to negative film except that the three emulsions are coated on a paper base and the masking couplers are not present. The paper is exposed (through an optical enlarger or contact printed) with the color negative and processed in a similar manner to the film.

Time did not permit my visiting the Eastman Kodak Company's Kodacolor processing laboratories while I was in Rochester; however, I have been led to believe that, like Kodachrome, it is processed on a continuous basis with the prints being exposed on long rolls.

1 "Color As Seen and Photographed", Eastman Kodak Company, Rochester, New York, 1951.

EKTACOLOR PROCESS

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General Discussion

In 1947 the Eastman Kodak Company announced a new color-complementary negative film, called Ektacolor, (a higher quality Kodacolor for the professional) which is intended to be processed by the user or other companies. From the negative, transparencies can be printed on another film called Ektacolor print film. This provides an easy method of obtaining several transparency copies of a picture, (Making duplicate transparencies of Kodachrome, Ansco or Ektachrome transparencies is a difficult process usually resulting in a loss of quality.) and a means of obtaining large transparencies through enlarging when printing. (The Eastman Kodak Company has an 18 x 60 foot transparency on display at the Grand Central Terminal in New York City; an example of what can be done with Ektacolor.) Ektacolor color negatives also eliminate the need for making separation negatives and masks for printing by the Dye Transfer process.

It has been rumored that Kodak has a high quality dye coupler print paper, soon to be released, with which to make prints (in any size) from Ektacolor negatives. The quality of the prints is said to be better than those obtainable from Printon or Kodachrome prints but not as good as Dye Transfer or Carbro prints.¹ When such a paper is available,

1 Mr. Mann of the Eastman Kodak Company Professional Studios, 343 State Street, Rochester, New York.

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it should be in definite demand by those who want one or a few high quality prints, (color portraits may very well become popular with such a process) but cannot afford the high set up cost of the first Dye Transfer print.

Technical Discussion

Ektacolor works, and is processed, in the same manner as Kodacolor, the only difference being the sacrificing of emulsion speed and a low price for quality in Ektacolor. As was mentioned earlier, very little information is presently available about this print paper, but it is rumored that it will be on the market soon.

DYE TRANSFER PROCESS

General Discussion

The Dye Transfer process, as it is being practiced today, is a refinement of an imbibition process that has been tried in many forms by numerous pioneers in the field of color printing for more than thirty years. The Dye Transfer process was brought out by the Eastman Kodak Company (who manufacture the materials for it) in 1947. From it are made many of the finest color prints available today. The Carbro process is the only process competing with the Dye Transfer for quality.

The minimum materials required to make the first 8 x 10 inch Dye Transfer print from a transparency, cost approximately \$2. A more realistic figure for the first top-quality print results is about \$5, (Additional cost is for masking film and an allowance for a trial run.) with the cost of materials for the second and successive prints, approximately 9 cents a print.

There are a great number of companies throughout the country carrying out the Dye Transfer process. Their prices (See fig. 4) vary from \$15 to \$200 for the first 8 x 10 inch print (the price above \$5 going for labor, overhead, and profit). There is a definite relationship between price and quality, although it is by no means linear; a point of diminishing returns is reached after certain steps toward high quality have been carried out. For all sizes above 8 x 10 inches, (they are available in sizes to 40 x 60 inches) the price increases much less than proportionally. All of the

Com- pany	QUANTITY									
	<u>One</u>	<u>2-6</u>	<u>6-12</u>	<u>12-24</u>	<u>25-50</u>	<u>51-99</u>	<u>100-200</u>	<u>200-500</u>	<u>500-1000</u>	<u>over 1000</u>
A	\$200									
B	175									
C	150	\$25.00*	\$22.50*	\$18.75*	\$15.00*	\$12.50*	\$10.00*			
D	95	4.00*								
E	75	8.00*	8.00*	6.50*	6.00*	5.00*	4.25	\$3.60	\$3.20	\$2.50
F	60	7.00*	5.50*	7.00	6.00	4.25	3.00	2.50	1.50	
G	60	7.00*	5.50*	7.00	6.00	4.25	3.00	2.50	1.50	
H				5.00	3.00	2.50	2.00	1.75	1.50	1.00
I	44	11.00	11.00*	7.50*	5.00*	4.00*				
J	40	4.00*	3.00*	2.50*	2.50*	2.25*	1.90*	1.90*	1.90*	1.25*
K	40	2.00*	2.00*	2.00*	2.00*	2.00*	2.00*	2.00*	2.00*	2.00*
L	15	5.00*	5.00*	3.60*	2.50*	2.10*	1.90*	1.70*	1.70*	1.70*
M	3	3.00	3.00	2.10	2.10	2.10	1.80	1.80	1.50	1.50
N	3	3.00	3.00	2.75	2.50	2.00	1.50	1.50	1.45	1.40

FIG. 4. DYE TRANSFER PRICES OF COMPANIES A-L AND FOR COMPARISON, PRINTON PRICES OF COMPANIES M AND N.

*Plus first print price. As some companies add the price of the first print into duplicate print prices and others do not, it becomes difficult to compare them at a glance. Hence Fig. 5 is included, where at specific quantities, the cost of the first print has been added.

Com- pany	QUANTITY											
	<u>5</u>	<u>12</u>	<u>20</u>	<u>25</u>	<u>40</u>	<u>60</u>	<u>90</u>	<u>100</u>	<u>180</u>	<u>200</u>	<u>500</u>	<u>1000</u>
C	55.00	35.00	26.25	21.00	18.75	14.50	14.15	11.50	10.85	10.75	10.30	10.15
D	23.00	11.90	8.75	7.80	6.40	5.60	5.05	4.95	4.55	4.50	4.20	4.10
E	23.00	14.25	10.25	9.00	7.85	6.25	5.85	4.25	4.25	3.60	3.20	2.50
F	19.00	9.25	7.00	6.00	6.00	4.25	4.25	3.00	3.00	2.50	1.50	1.50
G	19.00	9.25	7.00	6.00	6.00	4.25	4.25	3.00	3.00	2.50	1.50	1.50
H			5.00	3.00	3.00	2.50	2.50	2.00	2.00	1.75	1.50	1.00
I	19.80	14.70	9.70	6.75	6.10	4.75	4.50	4.45	4.25	4.20	4.10	4.05
J	12.00	6.30	4.50	4.10	3.50	2.90	2.70	2.30	2.15	2.10	2.00	1.95
K	10.00	5.30	4.00	3.60	3.00	2.65	2.45	2.40	2.25	2.20	2.10	2.05
L	8.00	6.25	4.35	3.10	2.90	2.35	2.25	2.05	2.00	1.80	1.75	1.70
M	3.00	3.00	2.10	2.10	2.10	2.10	2.10	1.80	1.80	1.80	1.50	1.50
N	3.00	2.75	2.75	2.50	2.50	2.00	2.00	1.50	1.50	1.50	1.45	1.40

Fig. 5 . DYE TRANSFER PRICES OF COMPANIES C-L AND FOR COMPARISON, PRINTON PRICES OF COMPANIES M AND N, WITH FIRST PRINT PRICES ADDED IN WHERE APPROPRIATE.

(All figures in dollars)

- 2.2
- A Efros & Pergament, Inc.
 - B Evans Color Laboratories
 - C Langen and Wind Carbro Prints, Inc.
 - D Efros & Pergament, Inc.
 - E Kurshan & Lang
 - F A. B. C. Steel Equipment Company
 - G Color Corporation of America Photographic Laboratories
 - H Skokie Valley Colorgraph Company, Inc.
 - I Pavelle Color Inc.
 - J Corona Color Studios
 - K Efros & Pergament, Inc.
 - L TriColor Laboratories

FIG. 6--KEY TO COMPANIES LISTED IN FIGS. 4 AND 5

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companies that I have visited that are using the Dye Transfer process, carry it out on a laboratory-type set up; primarily seeking the low quantity market; with most of their orders for one or two prints and few orders above a dozen. Although most of the companies' price lists give prices for quantity prints, most companies stated that such orders were few. While observing the process in operation, it occurred to me that once the operations have been carried out to make the first acceptable print, the making of successive prints could be carried out via a semi-mechanized means (not as adaptable, however, as Printon or Kodachrome). That which appealed to me was the high quality and the low cost of materials for the second and successive prints. It is possible to visualize a set up that might make it possible to turn out prints of identical quality with the first print, at a cost, including labor, not exceeding 20 cents a print. (The total cost of each print would be the 20 cents plus the first print cost divided by the number of prints.) This, however, is only a theoretical estimate on paper; it must be actually tried on an experimental basis before anything further can be determined. Some companies have expressed a desire to know of my ideas along this line; therefore, not knowing the value of these ideas, if any, I will not further discuss them in this paper.

In further investigating this idea, I visited all (except the smallest) of the companies in the New York area (there are none in New England) and have written letters to five of the better known companies throughout the country, carrying out the process. I found that two of the companies

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(one in Tampa, Florida and the other in Illinois) have mechanized the process to some extent, but were unwilling to reveal any details of their operation. Their prices (See fig. 4 -companies G and I) left, in my mind, something to be desired. They may not have exploited a mechanization idea as fully as might be possible.

The companies with first print prices below \$60 leave much to be desired in terms of quality of the print. These low prices are only realized by not performing adequate masking procedures and not spending enough time (some companies make one print, note its deficiencies, and completely repeat the first print process to get a better print) to accurately balance color and contrast. Their quantity prints do not maintain uniformity.

Technical Discussion

Soon after the start of the investigations of the various processes, it became apparent that the Dye Transfer process had a high potential of filling the high quality-medium quantity gap at a low price. Hence, a large percentage of my time has been spent studying this process and visiting companies carrying it out.

The process is carried out in the following manner:

1. From a set of masked separation negatives, positive prints of the ultimately desired size are made from each negative on a special film called matrix film. Matrix film has a transparent support on which is coated a light sensitive gelatin emulsion that has dispersed throughout it, a light absorbing dye. The matrix film is exposed through the transparent support with the following results:
 - a. Where little light strikes the matrix film, only a short depth of the light sensitive emulsion is exposed, as the light is absorbed by the light absorbing dye. (See fig. 7)
 - b. Where bright light strikes the matrix film, a greater depth of light sensitive emulsion will be exposed.
2. The Matrix films are now developed (in a tanning developer) in such a manner, that where light has exposed the emulsion, the gelatin becomes hard. Where the emulsion is unexposed, the gelatin becomes soluble in hot water.

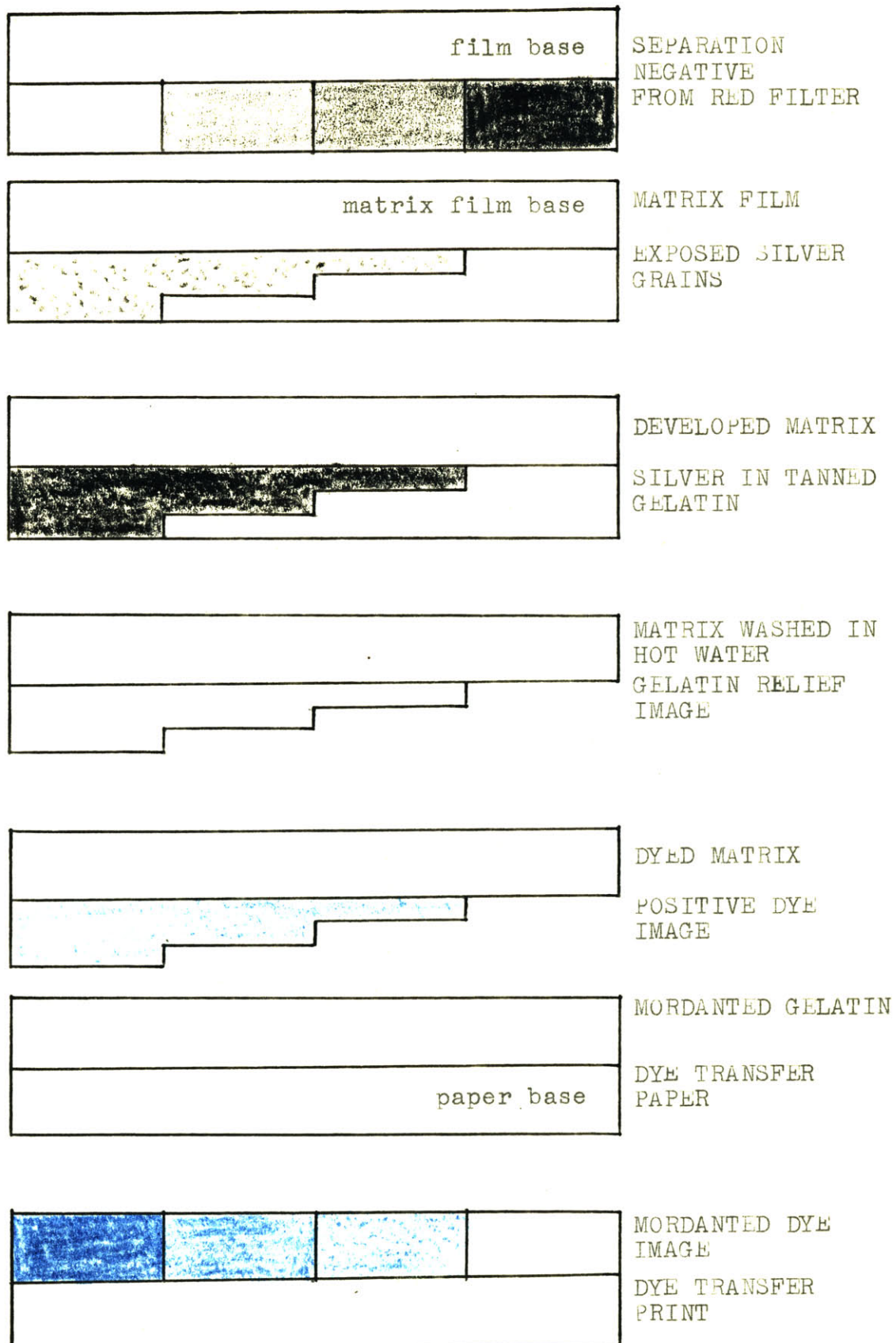


FIG. 7--SCHEMATIC DIAGRAM OF DYE TRANSFER PROCESS

- .00
3. The matrices are washed in hot water which dissolves the unhardened gelatin. What has resulted are matrices that are relief images of the original subject.

Making fully masked separation negatives and a balanced set of matrices, takes an experienced worker about eight hours for top quality work. As in Carbro, a good worker is paid as high as \$10,000 a year.

4. The matrices are placed in dyes; the matrix from the red filter in cyan (minus red) dye, from the green filter in magenta (minus green) dye, and from the blue filter in yellow (minus blue) dye. The matrices are left in the dye until the gelatin is fully saturated (about 5 minutes). They are next rinsed (for one minute) in an acid bath, the concentration of which is used to control, to some extent, the concentration of the dye held in the matrix and hence the density of the dye in the final print.
5. The matrices are placed, one after the other, on a piece of gelatin coated paper that has been prepared (mordanted) in a bath giving it an affinity for the dye in the matrix. The dye slowly (2-3 minutes) transfers from the matrix onto the print. Each matrix is placed in correct register before the dye transfers.
6. After each matrix has transferred its dye to the print, the final print is dried. The matrices can be water rinsed (one minute) and returned to the

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dyes and retransferred to make a number of prints.

If Ektacolor negatives are the starting point, a special matrix film (panmatrix film), sensitive to all colors, is used and exposed directly from the Ektacolor negative through three filters, thus eliminating the need for making masked separation negatives.

As one can see from the above description, there are a great number of variables in the process, all of which must be controlled for uniform results.

Exact details for carrying out the Dye Transfer process are set forth very clearly in two publications by the Eastman Kodak Company entitled "Color Separations and Masking" and "Kodak Dye Transfer Process". These books, in addition to giving step-by-step how to do it details, give suggested laboratory layout and equipment recommendations.

All of the companies that I have visited and all but two of those that I wrote to, were using a procedure and layout very similiar to that recommended by Kodak, which calls for the entire handling of the matrices and final print paper by hand. The main differences noted were in the way in which the registry is handled (a company in Staten Island, New York makes some registry equipment that, although initially expensive, makes the problem of registration very simple) and in some cases (of those companies with the top quality and prices) more intricate (secret) masking procedures were carried out.

The Kodak procedure appears to be efficient where one to a half-dozen prints are required; but where quantity

orders are being solicited, as many of the company price lists show they are, I believe a procedure could be set up that would many times cut the skilled labor now required, to produce the second and successive prints, then orders would be received for quantity prints.

In my visits to the various companies, I was interested in finding, in addition to their prices, seeing the general layouts and observing the quality of their work, the answers to many small detail questions that are not answered in the available literature. Some of these questions and the trend of the answers that I received, if uniform, are listed below. Many of the answers to my questions were often controversial or unknown by those whom I talked to,¹ however, I have included only those answers that most of the people concurred upon.

Q. Does the speed of the dye transfer increase if heat is applied? If so, what are the ill effects, if any?

A. Heat will increase the speed of transfer, but it is felt that the amount of increase does not warrant the increased effort. The dyes are apt to bleed (spread out in the gelatin, causing a loss of detail) with the application of heat.

Q. Can the speed of dye absorption and dye transfer be increased by using low contrast matrices and a higher dye concentration? Would quality suffer if this were done? Would the number of transfers possible before

1 See Appendix 3.

quality

falls off become less if this were done?

- A. Most of the people had not thought of attempting this but felt it would work with some loss of quality. Kodak must have set the particular balance now recommended to give the best quality. The thinness of the matrices would probably shorten their usable life.
- Q. Can the speed of dye transfer be increased by increasing the affinity (the mordanted bath is made more basic) the dye has for the paper? What happens if this is done?
- A. This very definitely will increase transfer time and if anything, will improve quality. However, the dye starts transferring as soon as the matrix comes in contact with the paper and no time is provided to insure proper registry. If a means for having the matrix contact the paper, in its correct position for transfer, immediately could be devised, this step could be taken.
- Q. Must each transparency receive a different treatment, in making the masks, separation negatives and matrices, or can the procedure be standardized? If the procedure can not be completely standardized, can the variables be confined to one step of the procedure, rather than be present in all steps?
- A. The procedure can only be standardized with a loss of quality. Each variable has a slightly different effect, i.e., one variable may control contrast in

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the highlights and another variable may more effectively control it in the dense portions of the subject. Obviously, if one of these variables were standardized, control of the contrast in either the highlights or dense portions of the subject would suffer. If the right variables were chosen to be standardized, acceptable, but not the best color prints, could probably be realized.

Q. Why do you feel that photographers are not using Ektacolor color negative film when they know the work will be reproduced by Dye Transfer? If the quality is improved, do you feel that not being able to see the results immediately will become accepted as we accept this feature in black and white photography?

A. At present Ektacolor gives a grainier picture than does a transparency. The film, as now being manufactured, has too wide a variance in both color correction and contrast from emulsion to emulsion, making the photographer unable to predict his results as he can with color transparencies. (I was told, while at the Kodak Research Laboratories, that these faults have been corrected in the laboratories but considerable time will lapse before these improvements are out on the market.) The photographer likes to see the results of his work before the (Dye Transfer) print maker produces the final print. Most of the people questioned, felt that the

photographer would accept this when the quality begins to exceed (as it eventually will) the quality obtainable with transparencies.

Q. Are large matrices, such as 16 x 20 inch, harder to handle than 8 x 10 inch matrices?

A. No. Not with a trained worker.

Q. How important is it to wash the matrices before returning them to the dye?

A. It seems to be unimportant as long as the same treatment is given to all the matrices.

Q. Can the time the matrices are in the first acid rinse be shortened or lengthened by changing the acid concentration?

A. No one seemed sure of this, but could see no reason why not.

Q. Is the problem of dust contaminating the matrices and solutions a real one?

A. Yes. The presence of dust will necessitate the prints having to be retouched. This is a variable that can and should be controlled by air-conditioning and humidity control. (A high humidity will keep dust down.)

At this point, I wish to mention another process that I have discovered but could not adequately investigate, as time was too short. This process is called Collotype and is very old, having been developed over a century ago. I mention it here, because the printing plate is a matrix, very similiar

to that used in Dye Transfer, differing in that the unhardened gelatin is not washed off in warm water. Instead, on the press it absorbs cold water (the hardened portion does not) and a greasy water repellent ink is used (as in Offset printing) which is received by the hardened gelatin (where there is no water) and is transferred to the paper.

I have found very little information about the process in modern literature, except the histories which mention that it was popular before Fredric Ives invented the halftone screen in 1881. The demand, at that period, was for a printing process capable of printing great quantities of uniform prints, the Collotype process would not satisfy this demand. The matrices would wear out quickly (after a few thousand prints) and was also greatly affected by temperature changes, an uncontrollable variable in those days. Collotype was capable of giving a very fine print, (some of the best in its time) however, it could not be depended upon. It may be that with the controls we have today, the Collotype process could be adapted to fill the needs of the process being sought; it certainly would be worthwhile looking into.

A search of the old literature would probably reveal more information and I have recently learned that one company (Meriden Graveure, in Meriden, Connecticut) has, or is doing, some work with Collotype. However, I have not had a chance to correspond with them as yet.

GRAPHIC ARTS

General Discussion

The Graphic Arts, or printing industry, produces color prints to fill the high quantity market demands, with prints up to 4,000,000 ("Life" magazine) being a common occurrence-- however, it is the lower limit of the Graphic Arts process we are interested in, in this paper. The high set up charge of all Graphic Arts processes, can only be offset by a long-run, as once the presses are set up, the cost per print becomes very small (hardly more than the cost of the plain white paper it is printed on). Hence, it is the set up cost we are most concerned with.

There are three processes in widespread use in the Graphic Arts industry; photolithography (offset), letter press and graveure. In order to produce a color print, all of the processes start with separation negatives from which three or four metal plates are made. (The fourth plate is for black ink which, as well as being used for lettering, is used to obtain strength of detail and to produce neutral shades of gray which are difficult to obtain with the three inks.) When set up in the presses, the plates will apply ink (cyan, magenta, yellow, and often black) to a white sheet of paper.

It is impossible to make a blank statement as to the preferability of one process over the others. Each has its advantages and disadvantages, and on some work, all three processes will produce equally good prints. With graveure, it is possible to print at extremely high speeds. Low grades

of paper may be used with both graveure and offset, but with letter press, a high quality paper is necessary.

To give the reader some idea of the type of work being produced by the different processes a list of some popular publications and the method by which they are printed is shown in figure 8.

There are no standard prices in the printing industry; each job is bid separately. In trying to obtain some sort of a price estimate, four printing companies were visited. One company¹ stated that the minimum number of impressions that they would consider is 100,000, as all of their presses were large, high speed machines. The second company² stated that the smallest process color job they ever did was of six 8 x 10 inch pictures with 3,000 copies of each; their price was \$4,500. This was a special job for a steady customer, however, and they did the job at estimated cost. Breaking this figure down, for 3,000 copies of one picture, their figure was \$750. The cost of paper (heavy weight), ink, cutting, and packaging for 1,000 copies is about \$15. The price per print breaks down as shown in figure 9a.

The third company visited³ was a letter press company. They had never done a small quantity job in process color, but were willing give me an estimate for a job at cost. Starting with a 5 x 7 inch transparency and desiring 8 x 10

1 Forbes Lithograph Company, Chelsea, Massachusetts.
2 Rand, Avery & Gordon, Inc., Boston, Massachusetts.
3 Oxford Print Company, Medford, Massachusetts.

Printed by Letterpress:

"National Geographic

"Holiday"

"Life"

"Saturday Evening Post"

"Colliers'"

Many calenders, annual reports and catalogues

Printed by Offset:

'Some parts of "Fortune" Magazine

Most outdoor advertising displays

Many calenders, annual reports, catalogues and a wide
variety of advertising displays.

Printed by Graveure:

Most Sunday newspaper color sections

Cover of "Look" Magazine

Many calenders, annual reports and catalogues.

FIG. 8--LIST OF SOME OF THE POPULAR PUBLICATIONS AND THE
METHOD BY WHICH THEY ARE PRINTED.

Figure 9a and 9b

	<u>Number of Prints Required</u>							
	<u>5000</u>	<u>2500</u>	<u>1000</u>	<u>500</u>	<u>250</u>	<u>100</u>	<u>50</u>	<u>25</u>
a.	.17	.32	.77	1.42	2.80	7.50	15.00	30.00
b.	.19	.36	.87	1.75	3.50	8.50	17.00	34.00

ESTIMATED COST IN DOLLARS OF 8 x 10 INCH COLOR PRINTS
BY GRAPHIC ARTS PROCESSES.

inch prints, the estimate as as follows:

Set of four 8 x 10 inch color corrected process plates.	\$625
Set of electroplates (copy plates).	70
Lock-up plates for mounting in press.	36
Press-makeready	120
Total set up cost	<u>\$851</u>

The cost of paper, ink, cutting, and packaging is about \$15 a thousand. The price per print breaks down as shown in figure 9 b.

A fourth company⁴ later contacted, gave a similar estimate. All of the companies stated that they were not in business for short run processes like these and could not estimate what would be a fair profit rate. They also felt that their overhead per job would have to be figured at a higher rate and that they would not want to handle this type of work as most of their profits resulted from the long runs, not the set up. The investment in equipment is very large and the burden of writing this cost off could not be absorbed in such an operation, as the ratio of down time (set up time) to running time would become extremely high.

⁴ Folsom Engraving Company, Boston, Massachusetts.

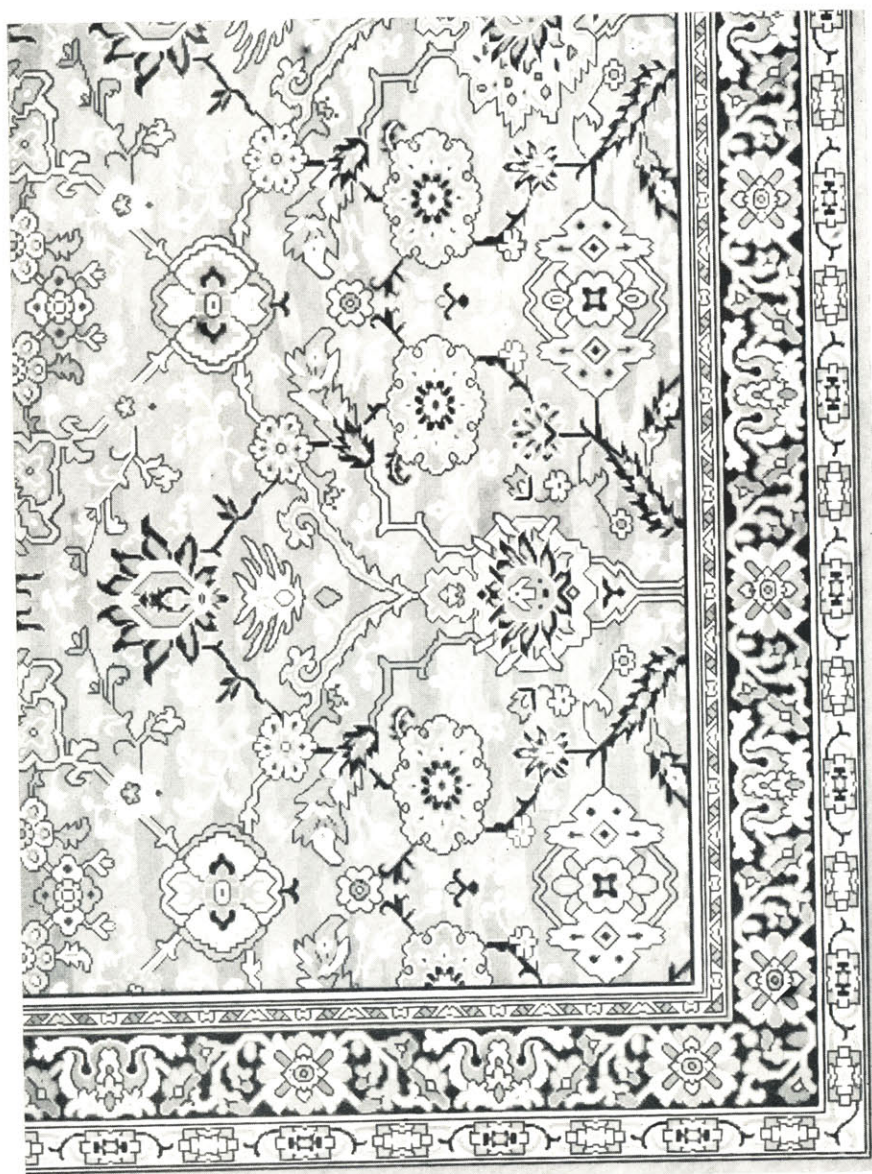
Technical Discussion

While the three processes, letterpress, offset lithography, and graveure are similiar, there are enough differences in each to make it worthwhile discussing them separately.

The letterpress process, starting with transparencies or copy work, makes what is known as halftone cut-out negatives. These negatives are actually separation negatives except that a halftone screen has been inserted a short distance in front of the film, which breaks up the continuous tone images produced by the lens of the camera into dots whose fractional areas represent the amount of light received from each area of the subject. There are two tones produced-- a black for the dots and white where there are no dots. There are no inbetween grays. The negatives are printed on a light-sensitive copper plate; the sensitive coating becoming hard where light hits it and water soluble where unexposed. The copper plates are now etched, small holes being eaten in the copper where no hardened coating exists. After being etched to a certain degree, the hardened sensitive coating is removed and the plates are locked up in a proofing press. Ink is applied to the unetched parts of the printing plates, the plates brought in contact with the print paper and the ink transferred to it. Progressive color proofs (see fig.10) are then made. The first set of proofs will differ greatly from the subject in both color fidelity, and contrast range. This, besides being due to the non-ideal printing inks, is further amplified by the nonlinearity of the halftone and



Fig. 10 PROGRESSIVE PROOFS.











engraving process.

It is at this point that the skilled color-etcher takes over the printing plates and by hand etch techniques, followed by numerous proofing operations, eventually develops a set of plates that will produce color prints that are a good reproduction of the original subject. The degree of resemblance being a direct measure of the coloretcher's skill and patience. The amount of time that a color etcher will spend with a set of 8 x 10 inch plates to achieve a quality suitable for magazine advertising reproduction, is usually between forty and fifty hours.

The finished plates, if a large number of reproductions are to be made from them, are electrotyped; this being a mold process by which duplicate sets of plates can be made. If, as is starting to be done by the more progressive printing houses, a masking procedure (such as is described in an Eastman Kodak Publication, "Masking Color Transparencies for Photomechanical Reproduction") is used in preparing the halftone cut out negatives, the time to make the negatives--with masking--will take about four hours longer. The time required then, for the color etcher to achieve the same quality reproduction will be only four or five hours.

Offset lithography starts with a set of separation negatives from which are made, using a halftone screen, a set of positive transparencies. These positives are processed in such a manner that the dots are slightly larger than will be finally desired.

It is at this point in the process, that the color etcher carries out the color correcting. He has the original copy work or color transparency to work from and is so trained, that by looking at the size of the dots (through a magnifying glass) in each positive, can tell what dots need to be made smaller in order to have a satisfactory color rendition when the printing plates are made. He makes the dots smaller by applying a bleaching solution to certain areas of the transparency. This color correction is carried out in small areas throughout the entire picture. Color correcting is a long arduous task, requiring a high degree of skill. This phase of the plate making operation accounts for the major portion of the expense, as the color etcher is highly paid, and takes a long time to correct a set of plates. If the work is critical, a set of plates can be made from the partially corrected positives and a set of proofs printed. With this aid, final correction is carried out. These proofing plates will necessarily be discarded.

The plates are made in the following manner: Zinc plates are given a minutely rough surface (called graining and carried out by placing small steel balls on the zinc plate as it is rocked back and forth). The plates are then coated with a light sensitive emulsion and exposed to light while in contact with the halftone screened positive transparencies. The exposed portions of the emulsion are hardened and the unexposed, washed off, leaving the bare metal. The plate is now given a slight etch, just enough to remove the

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roughened portion of the plate. The hardened emulsion is removed, leaving a plate with certain areas remaining rough and others etched smooth.

The plates are locked up in a press and damping rollers, containing water, are applied to them. The water will adhere to the plate in the roughened areas, but not in those that are smooth. A water repellent (greasy) ink is now applied to the plate and due to the water, only adheres to the smooth portions of the plate. The ink is transferred to a rubber roller, called the offset blanket, which comes in contact with the paper and transfers the ink to it.

The graveure printing process starts with a set of separation negatives from which are made continuous tone positives that are retouched in the same way as in offset, with the exception that the color etcher is dealing with continuous tones rather than halftones. A proofing operation is seldom run in graveure.

The continuous tone positives are contact printed (with a graveure screen in between) on a light sensitive "carbon" tissue. This tissue hardens (in relief) in proportion to the amount of light exposure it has received; i.e., the portion receiving the greatest amount of light hardens throughout the entire thickness of the tissue; those portions receiving less exposure, harden through only a portion of the thickness of the tissue.

The tissue is placed in warm water, the paper support removed, and the unhardened portions washed off. The carbon tissue, containing the relief image, is placed on a copper

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roll and the roll immersed in an etching solution. The solution quickly penetrates the thin parts of the tissue and starts etching the plate. The thicker portions are not so quickly penetrated and hence, at the end of the etching time, the copper beneath the thick portions of the tissue will not be as deeply etched.

The purpose of the graveure screen (mentioned previously) was to break the continuous tones into small areas of different tones, so as to form a large number of small ink wells, (20,000/square inch) varying in depth according to the darkness of the image when the copper was etched.

The engraved cylinders are mounted in a press, the bottom of the cylinder being immersed in the ink. The small wells pick up ink, move past a "doctor" blade, that scrapes off the excess ink, and transfer the remaining ink to the paper.

In all of these processes, the four colors may be run on one 4-color press, two 2-color presses or on four single color presses.

General Discussion

The Eastman Kodak Company, aware of the high plate-making and set up cost and the demand for a low cost short-run process, has developed a short-run process known as Ektalith. By standardizing the entire process and using automatic machinery, they have realized great savings in the set up operation.

Their starting point is a 35mm transparency and the finished print is postcard size. All exposures are automatically timed and color correction is a standard photographic procedure. No hand correction is carried out in any part of the process. Four of these postcard pictures are printed on an $8\frac{1}{2} \times 11\frac{1}{2}$ sheet of paper. They are printed one color at a time on a specially fitted, multigraph, small press. The set up cost is about \$10 per picture and the paper, ink, and cutting cost is about \$15 for 1,000 four-picture sheets; giving a cost of about \$15 for 1,000 copies, or $1\frac{1}{2}$ cents a copy.

The quality of the pictures is good, but leaves much to be desired for many types of commercial work. Investment in equipment is about \$10,000. If a change in the size of the final print or starting-size transparency is desired, new equipment for each change would be needed at an estimated

1 All information on this process was related to me by the men at the Eastman Kodak Research Laboratories, who have been developing the process.

cost of about \$3,000 per set up, providing the final print size does not exceed $8\frac{1}{2} \times 11\frac{1}{2}$, the maximum limit of the press.

If a larger print is desired, costs would increase many fold, rather than proportionally, and the same good quality would probably not be forthcoming at the present stage of development.

The merits of the process certainly warrant a great deal of further development. Eastman Kodak is offering the process to anyone desiring it, and at least one company (The Princeton Polychrome Company of Princeton, New Jersey) is using it.

Technical Discussion

As has been previously mentioned, Ektalith is a three-color, (no black printer) offset process that has been rigorously standardized. The 35mm (cardboard mounted) color transparency is placed in a holder with a piece of masking film. This single mask is automatically exposed in a special machine and is processed (usually with many others exposed at the same time) in a tank. The purpose of this mask is to reduce the overall contrast of the transparency and partially correct for the deficiencies of the worst dye. The processed mask is placed back in the holder with the transparency (registry pins insure its correct position) and the holder placed in an automatic negative exposing machine, which will, at the push of a button, correctly expose the three halftone negatives (200 lines per inch) side by side, on a single sheet of film. At the same time of exposure, registry holes are punched in each negative. These sheets of film are tank processed and the processed negatives quickly examined. If it is obvious, that the results will not be correct at this point, a new set of negatives are made with a suitable correction in exposure.

Four different negatives of one printing color are placed on a vacuum registry board, in contact with a (multi-graph) aluminum plate which is purchased with a roughened surface and sensitive coating already on it. The plate is exposed and etched. Etching consists of swabbing the plate with a piece of cotton soaked in a solution, and then immediately cleaned with a solution which stops the etching action

and removes the light hardened coating.

At Kodak, one, one-color press was being used, which meant that one color was printed, the press cleaned, another plate and different color ink put in, that printed, and the third color done in the same manner. The inks being used were very slow drying, requiring a day before another color ink could be printed on top of it. One day was spent in printing many cyan plates, the next, magenta, and the third day, the yellow. This reduced press cleaning to a daily operation. If a larger scale operation was to be undertaken, it might very well be worthwhile having three presses, so that the tedious operation of cleaning the presses could be eliminated.

CONCLUSIONS

After carrying out the investigation discussed in the previous pages, I feel in a position to pose the eight conditions (stated in the introduction) to each process; this has been done in chart form for the convenience of the reader. (See figs. 11-18)

The final correlation (See fig. 19) shows the Dye Transfer process to be the best, the Graphic Arts process second, and the Ektalith process third. While this correlation does not give a true picture, because all of the conditions cannot be given equal weight, (price and quality are most important) it does serve to roughly evaluate the potential of each process in filling this niche at each processes' present stage of development.

Rapid strides have been made in improving all of the processes in the past decade and this chart may be meaningless within the next year or two.

It is the author's belief that the Dye Transfer process has the highest potential; it is capable of giving top quality, will take a wide variety of starting material, can be made in large sizes, and I believe, can satisfy the low price demand if suitably mechanized. The purpose of this thesis has been satisfied by providing the data necessary for reaching this conclusion. It is from here that I would continue in writing a Master's thesis on the "Possibilities of Setting up the Dye Transfer Process for Quantity Color Prints." This thesis would include a thorough market

Condition 1--A set up cost involving little or no expense.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Remarks
Printon				X	Making second and successive prints requires repeating the entire process, except that color balance, correct contrast and exposure have been determined.
Kodachrome				X	
Kodacolor				X	
Ektacolor				X	
Carbro	X				Can not be set up for repetative production.
Dye Transfer			X		Cost--\$20-\$100 for 8 x 10" print, dependent on quality.
Graphic Arts Offset, Litho and Graveure	X				Costs in \$500-\$1,000 region for 8 x 10" print.
Ektalith			X		Cost--\$10 for 3 x 4½" print.

Fig. 11

Condition 2--Once set up, the actual print making should lend itself to mechanization to an extent that will minimize the need for highly skilled labor.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Remarks
Printon				X	Can be printed on long rolls of film in a single operation and can be continuously processed by automatic equipment.
Kodachrome				X	
Kodacolor				X	
Ektacolor				X	
Carbro	X				Must remain a hand operation.
Dye Transfer				X	Can visualize semi-automatic print making machinery.
Graphic Arts Offset, Litho and Graveure				X	Produced on presses that need little attention once set up.
Ektalith				X	

Fig. 12

Condition 3--The cost of materials for producing final prints should be low.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Remarks
Printon	X				The cost of the print paper and the chemicals to process them represent a major cost of the entire print. Hence, little price reduction can be realized on quantity orders.
Kodachrome	X				
Kodacolor	X				
Ektacolor	X				
Carbro		X			High cost, but small percentage of total cost.
Dye Transfer			X		Cost is gelatin-coated paper (3¢ a sheet for 8 x 10" print) plus dyes (6¢ a print).
Graphic Arts Offset, Litho and Graveure				X	Cost is only plain white paper and ink.
Ektalith				X	

Fig. 13

Condition 4--The process should be able to utilize a wide variety of starting material.
 (Copywork, transparencies [all sizes] separation and color negatives.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Remarks
Printon		X			Only color transparen- cies. (Any size)
Kodachrome		X			
Kodacolor	X				Only Kodacolor negatives.
Ektacolor	X				Only Ektacolor negatives.
Carbro				X	All but color negatives.
Dye Transfer				X	All.
Graphic Arts Offset, Litho and Graveure				X	All but color negatives.
Ektalith	X				Only 35mm Kodachrome transparencies.

Fig. 14

Condition 5--The quality must be very good.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Remarks
Printon	X				Not commercially acceptable, in most cases.
Kodachrome	X				
Kodacolor	X				
Ektacolor			X		Is expected to be of good quality.
Carbro				X	Best quality obtainable.
Dye Transfer				X	Top-quality.
Graphic Arts Offset, Litho and Graveure			X		Can be of top quality, but price becomes exceedingly to realize it.
Ektalith		X			Satisfys some commercial demands.

Fig. 15

Condition 6--Prints must be within a close tolerance of being identical.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Remarks
Printon			X		With very expensive, tightly controlled pro- cessing machinery uniformity can be held reasonably well.
Kodachrome			X		
Kodacolor			X		
Ektacolor			X		
Carbro		X			Too many variables involved to be able to hold uniformity.
Dye Transfer				X	Few variables; could be held constant by simple control of machinery.
Graphic Arts Offset, Litho and Graveure				X	Presses give very uniform results with proper adjustments.
Ektalith				X	

Fig. 16

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Condition 7--The price must be low in the 12-3,000 bracket, if the process is to compete with existing methods.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Remarks
Printon			X		Low price at low quantities. Would not compete at high quantities. (500 and up.)
Kodachrome			X		
Kodacolor			X		
Ektacolor			X		
Carbro	X				Price very high
Dye Transfer			X		Potentially low price for quantities above 50.
Graphic Arts Offset, Litho and Graveure		X			Price very high at quantities below 500.
Ektalith				X	Low price.

Fig. 17

Condition 8--Prints must be available in a wide variety of sizes.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Remarks
Printon		X			Available in sizes up to 8 x 10 inches. Printon can be obtained in sizes up to 16 x 20 inches, but price becomes very high.
Kodachrome		X			
Kodacolor		X			
Ektacolor			X or	X	Has not been announced. Expect sizes up to 40 x 60 inches.
Carbro				X	Sizes up to 16 x 20 inches.
Dye Transfer				X	Sizes up to 40 x 60 inches.
Graphic Arts Offset, Litho and Graveure				X	Size limited by capacity of presses.
Ektalith	X				Currently only 3 x 4½ inches.

FIG. 18

Summary of conditions 1 through 8.

Print Process	Does not fulfill	Fulfills to some extent	Fulfills reasonably well	Definitely fulfills	Score
Printon	2	2	2	2	Tied for 5th
Kodachrome	2	2	2	2	Tied for 5th
Kodacolor	3	1	2	2	Tied for 6th
Ektacolor	2	0	3-----1----	2	4th
Carbro	3	2	0	3	Tied for 6th
Dye Transfer	0	0	3	5	1st
Graphic Arts Offset, Litho and Graveure	1	1	1	5	2nd
Ektalith	2	1	1	4	3rd

Fig. 19

research (to satisfy my beliefs of the demand for such prints)
and detailed plans for organizing a company along these lines.
Whether I continue on for a Master's degree or not, I intend
to carry on these investigations on my own, after graduation.

APPENDICES

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APPENDICES 1a, b, and c

a Source of information on principles and theory of color photography.

R. M. Evans, W. T. Hanson, and W. L. Brewer, "Principles of Color Photography", John Wiley & Sons, Inc., New York, 1953.

D. A. Spencer, "Colour Photography in Practice," Pitman, New York, 1948.

"Color As Seen and Photographed," Eastman Kodak Company, Rochester, New York, 1950.

A.C. Hardy, "The Theory of Three-Color Photography", Journal of the Society of Motion Picture Engineers, Vol. XXXI, No. 4, October, 1938.

A.C. Hardy and F. L. Wurzburg, Jr., "The Reproduction of Color", Interchemical Review, Vol. 9, Nos. 1, 2 and 3, The Research Laboratories of the Interchemical Corp.

C. E. Kenneth Mees, "Photography", The Macmillan Co., New York.

R. M. Evans, "An Introduction of Color", John Wiley & Sons, Inc., New York, 1948.

b Source of information on the workings of the color print processes.

D. A. Spencer, "Colour Photography in Practice," Pitman, New York, 1948. (Carbro and Dye Transfer processes)

C. E. Kenneth Mees, "Photography", The Macmillan Co., New York. (Kodachrome process)

"Color As Seen and Photographed", Eastman Kodak Company, Rochester, New York, 1950. (Kodachrome, Kodacolor, and Ektacolor processes)

"Tricolor Pigment Printing", McGraw Colorgraph Company, Burbank, California, 1951. (Carbro process)

"Color Separation and Masking", Eastman Kodak Company, Rochester, New York, 1951. (Dye Transfer)

"Kodak Dye Transfer Process", Eastman Kodak Company, Rochester, New York, 1951.

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"Masking Color Transparencies for Photomechanical Reproduction", Eastman Kodak Company, Rochester, New York, 1952. (Graphic Arts)

Keith Henney, "Color Photography for the Amateur", McGraw-Hill, New York, 1948. (Dye Transfer, Carbro and Printon)

"The Art of Photoengraving", American Photoengravers Assoc., 1952. (Graphic Arts)

c Source of historical information.

Louis Walton Siple, "A Half Century of Color", Macmillan, New York, 1951.

Beaumont Newhall, "The History of Photography from 1839 to the Present Day", The Museum of Modern Art, Simon and Schuster, New York, 1949.

E. J. Wall, "The History of Three-Color Photography", American Photographic Publishing Co., Boston, 1925.

APPENDICES 2a and b

a Companies visited and contacts.

Corona Color Studios, 37 West 47 Street, New York, N. Y.
(Plant--5 Court Square, Long Island City, N. Y.)
Mr. Alfred Losch, President. (Dye Transfer)

Kurshan & Lang, 10 East 46 Street, New York, N. Y.
Mr. L. Zoref, Associate. (Dye Transfer and Printon)

Langen and Wind Carbro Prints, Inc. 18 East 49 Street,
New York 17, N. Y., Mr. Jerry Wind, Partner.
(Carbro and Dye Transfer)

Hfros & Pergament, Inc., 20 East 49th Street, New York
17, N. Y., Mr. Henry Pergament, President.
(Dye Transfer)

Peterson Color Labs, 149 West 54 Street, New York, N. Y.
Mr. Peterson, President. (Dye Transfer)

Pavelle Color Inc., 533 West 57th Street, New York 19, N. Y.
Mr. Leo Pavelle, President and Mr. Milton Berg, Sales
Department. (Printon and Dye Transfer)

Eastman Kodak Company, Kodak Park, Rochester, N. Y.
Research Laboratories. Dr. David MacAdam, Mr. Louis Condax,
et al., (Ektalith, Dye Transfer and Ektacolor)
343 State Street, Rochester, N. Y. Mr. Howard C.
Colton, Professional Services and Mr. Mann, Professional
Studios. (Dye Transfer and Ektacolor)

St. Clair & Price, 1101 Beacon Street, Boston, Mass.
Mr. Fred St. Clair, President. (Discussed Dye Transfer,
but company not carrying it out.)

Forbes Lithograph Manufacturing Co., Chelsea, Mass.
Mr. Drury, Estimating Department. (Graphic Arts-primarily
Offset)

Rand, Avery and Gordon, Inc., 371 Commonwealth Avenue, Boston,
Mass., Mr. Charles Temole, Sales Dept. (Offset and Letterpress)

Oxford Press, 4 Colby Street, Medford, Mass., Mr. Porter,
Vice-President of Sales and Mr. Kearney, Plant Supervisor.
(Letterpress)

Evans Color Laboratories, 67-17 Selfridge Street, Forest
Hills, N. Y., Mr. Edward Evans, President, (Dye Transfer
and Carbro.)

Folsom Engraving Company, 212 Summer Street, Boston, Mass.
Mr. Doane, Sales Dept. and Mr. Edwards, Chief color
etcher. (Letterpress engraving plates)

Cambridge Color Laboratories, 447 Concord Avenue,
Cambridge, Mass., (Printon)

b Companies corresponded with and contacts.

Color Corporation of America Photographic Laboratories,
610 South Armenia Avenue, Tampa, Florida, Mr. Howard
Yawn, Plant Manager. (Dye Transfer)

Skokie Valley Colorgraph Co., Inc., 5831 Dempster Street,
Morton Grove, Illinois, Mr. William Little, III.
(Dye Transfer)

A. B. C. Steel Equipment Co., Inc., First Avenue and
17th Street, Tampa 5, Florida., Miss Charlene Heald,
Lab Technician. (Dye Transfer)

Tricolor Laboratories, 1711 North Vermont Avenue,
Hollywood 27, California, Mr. Jack Whiting, Sales Manager,
(Dye Transfer)

Color Research Laboratories, Inc., Philadelphia, Penn.
(Dye Transfer)

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APPENDIX 3

Persons questioned on details of the Dye Transfer process.¹

Mr. Alfred Losch, President, Corona Color Studios

Mr. L. Zoref, Associate, Kurshan & Lang

Mr. Henry Pergament, President, Efros & Pergament, Inc.

Mr. Peterson, President, Peterson Color Labs.

Department Head of Dye Transfer Division, Pavelle Color, Inc.

Mr. Louis Condax, Mr. Howard C. Colton, Mr. Mann and
other lab technicians, Eastman Kodak Company.

Mr. Fred St. Clair, President, St. Clair & Price.

Mr. Edward Evans, President, Evans Color Laboratories.

Mr. Howard Yawn, Plant Manager, Color Corporation of
America.

Mr. William Little, III, Skokie Valley Colorgraph Co., Inc.

Miss Charlene Heald, Lab Technician, A. B. C. Steel
Equipment, Co., Inc.

Mr. Jack Whiting, Sales Manager, Tricolor Laboratories.

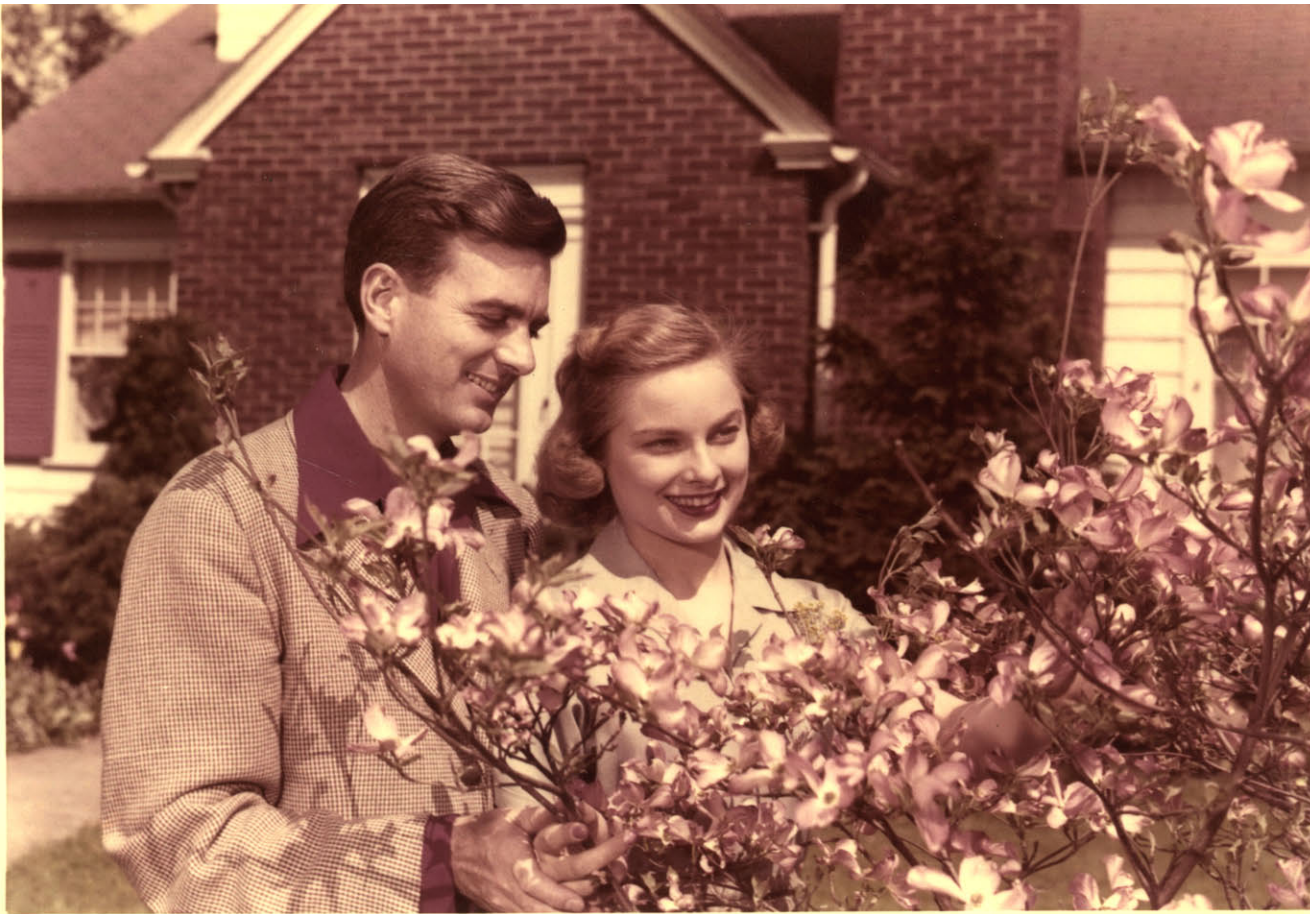
1 Addresses of companies listed in appendices 2a and b.



APPENDIX 4a--PRINT BY PRINTON PROCESS

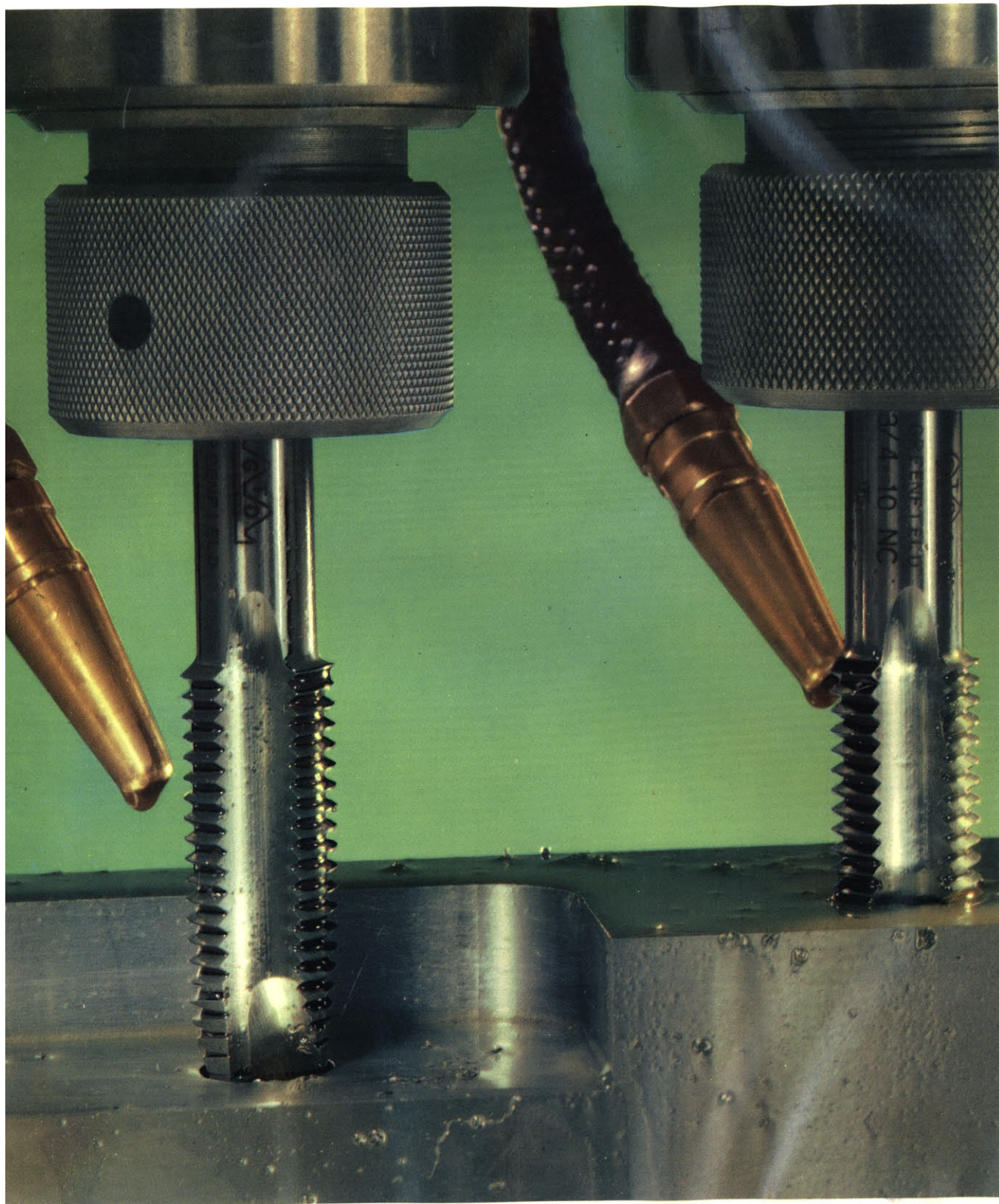


APPENDIX 4b---PRINT BY KODACHROME PROCESS



APPENDIX 4c---PRINT BY KODACOLOR PROCESS
and Kodacolor Negative

USED IN
ANOTHER PUBLICATION
REMOVED BY AUTHOR



APPENDIX 4e---PRINT BY OFFSET LITHOGRAPHY

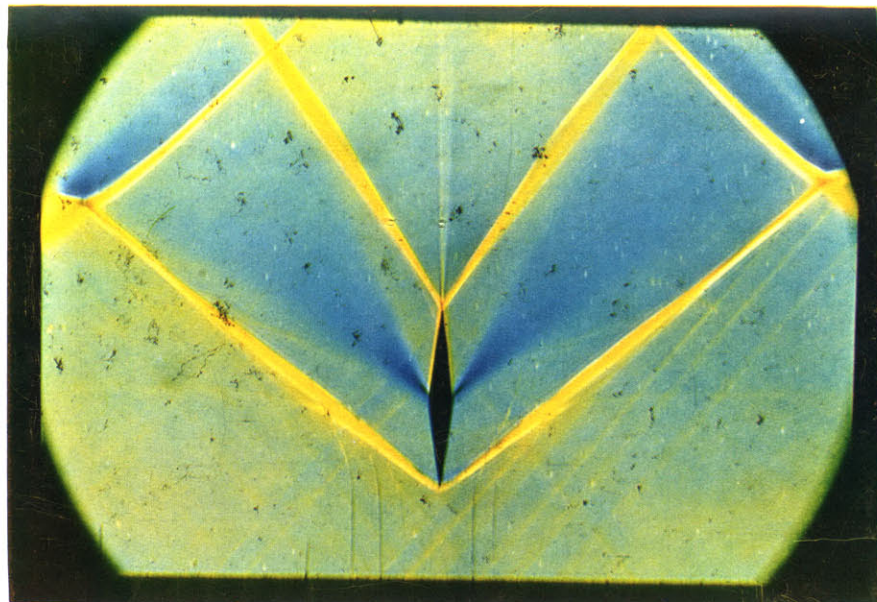
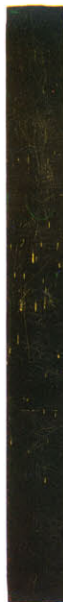
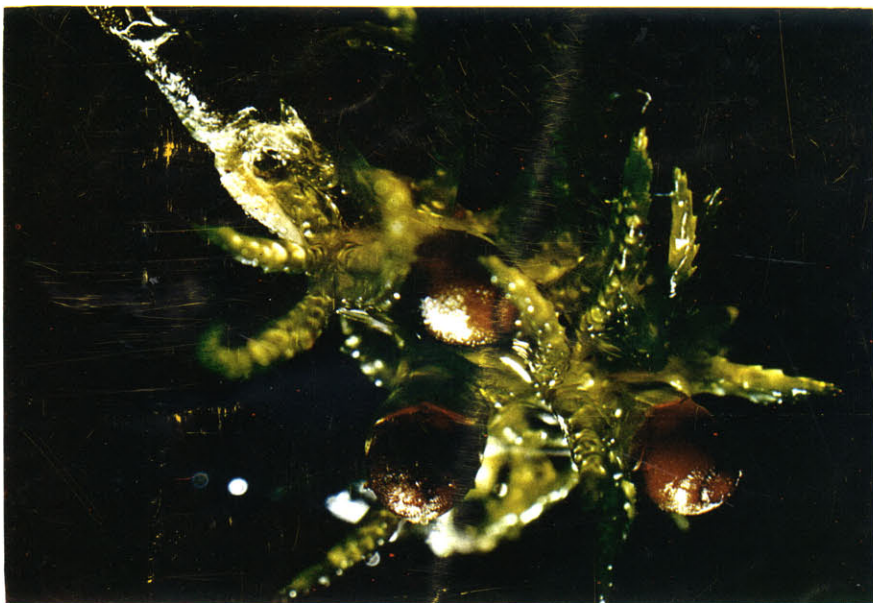


APPENDIX 4f---PRINT BY LETTERPRESS





APPENDIX 4h--PRINT BY EKTALITH PROCESS, PROGRESSIVE PROOFS AND
PORTION OF PRINTING PLATE



APPENDIX 4i---Ektalith Prints as they come from the press.

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